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This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of fourteen single-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.

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Volume VII - Washington, D.C.

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Office of Air and Waste Management
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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume VII

Washington, D.C.

FINAL REPORT

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Office of Air and Waste Management
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Research Triangle Park, North Carolina 27711

June 1976

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FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

This and the other 13 city reports are viewed primarily as working documents; thus, no effort was made to incorporate all the reviewer's comments into the text of the report. The comments were, however, considered during the preparation of Volume I and are included herein in order to alert the reader to different points of view. The 16 volumes comprising the overall study are as follows:

Volume	I - National Assessment of the Urban Particulate Problem
Volume	II - Particle Characterization
Volume	III - Denver
Volume	IV - Birmingham
Volume	V - Baltimore
Volume	VI - Philadelphia
Volume	VII - Chattanooga
Volume	IX - Oklahoma City
Volume	X - Seattle
Volume	XI - Cincinnati
Volume	XII - Cleveland
Volume	XIII - San Francisco
Volume	XIV - Miami
Volume	XV - St. Louis
Volume	XVI - Providence

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EXECUTIVE SUMMARY

Washington, D.C. is situated at the junction of the Potomac and Anacostia Rivers, on the Atlantic Coastal Plain. The climate is mild, with average precipitation. Washington is a nonindustrial city.

AIR QUALITY LEVELS AND TRENDS

Particulate levels have been gradually decreasing since sampling began in 1958, however, they were higher in 1974 than in 1973. Seven of the nine sites sampled during 1974 had levels below the national annual primary standards for TSP. The other two, both in the center city, had means of 92 and 102 $\mu g/m^3$. The annual mean of all sites sampling has been below the primary standard since 1971; in 1973 it was below the national secondary standard for TSP. Twenty-four hour standards are exceeded most often (up to 18 percent of the time) at the downtown sites.

NETWORK DESIGN

There were nine monitoring sites used for TSP sampling in Washington during 1974. In the latter part of the year, two additional sites began sampling. The sites cover the major types of land usage around the city: the residential, commercial, institutional, and downtown areas. However, there is little monitoring on the southeast side of the Potomac and Anacostia Rivers, areas which contain over 25 percent of Washington's major point sources. Most of the monitors are rather atypically placed, either quite high on top of tall buildings, low on the ground, or set far back from the street.

METEOROLOGY AND CLIMATOLOGY

Washington has a mild climate with an average amount of precipitation, and is situated in a generally flat area. Mean seasonal and annual mixing heights are not unusual, though afternoon mixing heights tend to be low. Numbers of heating degree days, surface wind speed, and wind speed through the mixing layer are also in the midrange of the 14 cities studied. Winds are generally from the south-southeast and the northwest.

URBAN ACTIVITY

Both traffic and subway construction activity appear to significantly affect TSP levels in the city, but their effect is difficult to quantify because of changes in meteorological conditions and anomalies of monitor placement. Local construction effects can more easily be determined at some sites, in their direct influence on particulate levels and their indirect influence on traffic patterns.

EMISSIONS

Washington, being a nonindustrial city, has a small estimated total particulate emissions (7,211 TPY in 1973). Its major point source emission category is electricity production (36 percent of the total). Incineration, which contributed about 4,500 TPY in 1969, has been replaced in part by solid waste recycling which, contributed only 116 TPY in 1975. Institutional facilities and military installations now account for the rest of the major point sources in the city. Estimates of area source emissions are small.

REGULATIONS AND ENFORCEMENT

Washington's regulations are very stingent for process equipment, incineration, and fuel burning equipment. Visible emissions are generally

prohibited. Little enforcement is necessary at point sources for compliance with standards for air quality control. The Washington, D.C. Bureau of Air and Water Quality Control is responsible for general field surveillance, which is done on a complaint basis.

REVIEWERS' COMMENTS

The draft report for each city was submitted to interested EPA, state, and local officials for comment on the contents and findings. Comments of an editorial nature were reconciled; comments of a substantive nature which reflect differences of opinion were compiled and are presented below.

Executive Summary	- The phrase "little enforcement is necessary" may be misleading since they do need to maintain the compliance of the sources they have; there are not many sources.
Air Quality Levels and Trends	- The NASN site may have relocated since 1957 when it was first installed.
Meteorology	- The correlation between meteorological parameters and short term fluctuations is very weak.

SECTION I

INTRODUCTION

NATURE OF THE AREA

The National Capital Interstate Air Quality Control Region (NCIAQCR) includes the following areas (see Figure 1): the District of Columbia; the cities of Alexandria, Fairfax, and Falls Church; Montgomery and Prince Georges Counties in the State of Maryland; and Arlington, Fairfax, Loudoun, and Prince William Counties in the Commonwealth of Virginia.

Topography and Climatology

The region is situated on the flat Atlantic Coastal Plain and the gently rolling Piedmont Plateau. The terrain to the east is generally flat with elevations of less than 100 feet above mean sea level. Gentle rolling hills with elevations of 200 to 500 feet extend to the Blue Ridge Mountains at the western edge of the region. These mountains warm and dry the westerly winds reaching the region. The AQCR is located 35 miles west of Chesapeake Bay, far enough inland from the ocean to escape the sea breeze effect. In general, the topography of the area permits free air movement with few channeling effects.

The AQCR experiences mild spring and fall seasons, hot humid summers, and cool but relatively short winters. The hottest month, July, averages 79 degrees and the coldest month, January, averages 36 degrees. The region averages about 4,200 heating degree days per season. The rivers and the nearby bay help to maintain high humidity with southerly winds

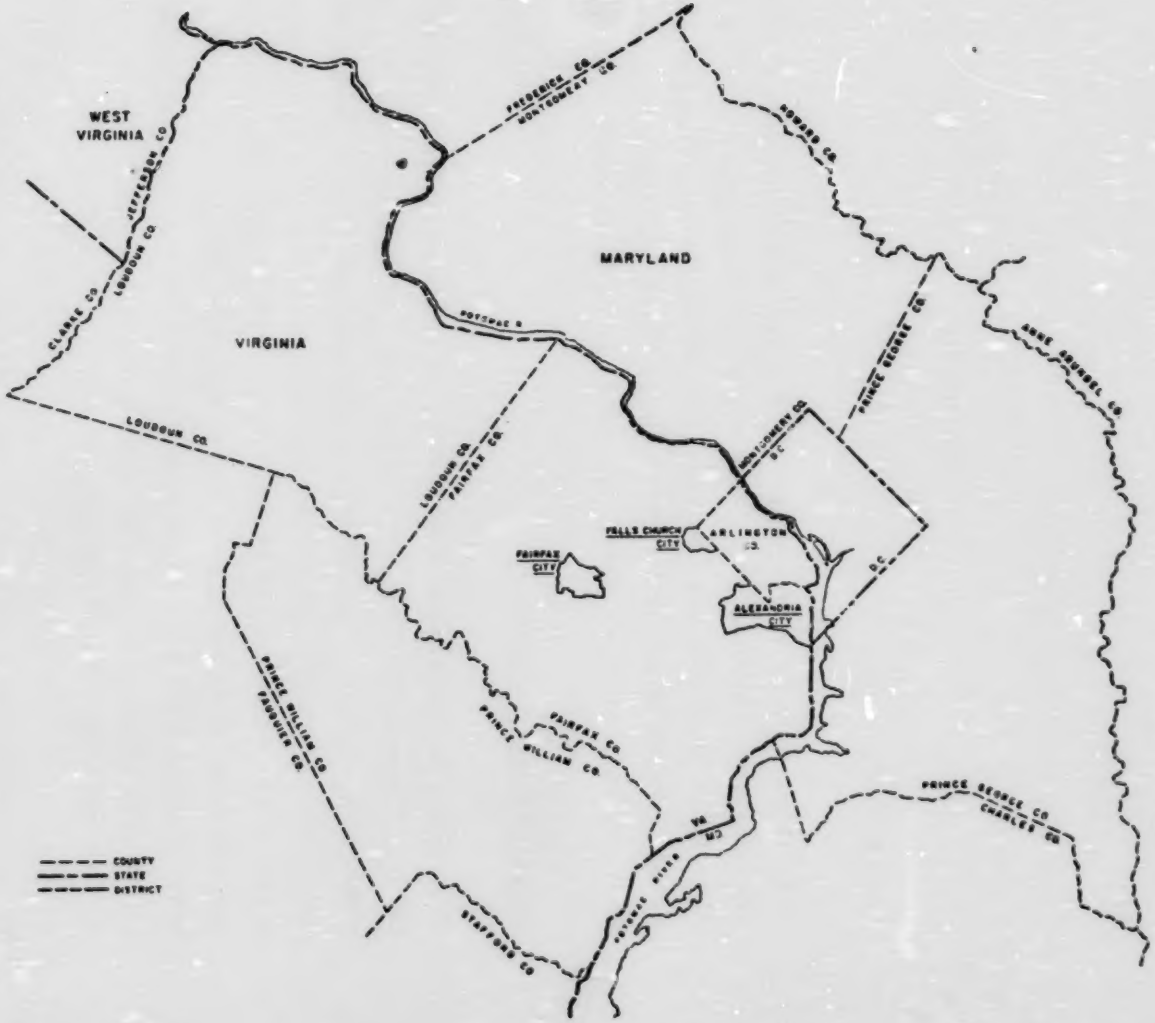


Figure 1. The National Capital Interstate AQCR

over the eastern half of the region. Measurable precipitation is evenly distributed throughout the year, occurring about 1 day in 3 except 1 day in 4 during autumn. The annual rainfall averages about 39 inches per year. Weather changes occur frequently, but periods of stagnating anticyclones, which contribute to the development of high pollutant concentrations, are not uncommon. During the 30-year period from 1936 to 1965, the area was affected by 48 stagnating anticyclones for a total of 231 days. Average duration of each situation was 4.8 days; and in three of the cases, stagnation persisted for 7 days or more. Of the 48 cases, 34 occurred during the months of August, September, and October.

The frequency of low-level inversions measured near the District of Columbia showed that they occurred about 40 percent of the time during autumn, about 35 percent of the time during winter, and about 30 percent of the time during spring and summer. Washington has been determined to have an average of 20 episode days per year in a 5-year period (mixing height $\leq$ 1500 m, wind speed $\leq$ 4.0 m/s).

Surface winds reported at the National Airport occur most frequently from the northwest during the colder months and from the south and south-southeast during the warmer months.

Population, Employment, and Land Use Patterns

At the 1970 Census, more than 2.9 million persons resided in the NCIAQCR, approximately 800,000 people (32 percent) within the District of Columbia (see Table 1). At that time, the population density for the region was 1,234 persons per square mile. Densities throughout the region ranged from 13,300 persons per square mile in the District to only 63 persons per square mile in Loudoun County. Although comprising 42 percent of the land area in the NCIAQCR, Prince William and Loudoun Counties contain only 5 percent of the population.

Estimates of population for the NCIAQCR for 1975 are placed at 3.5 million, or about 22.7 percent greater than 1970. It is also apparent from these projections, however, that the District of Columbia proper is approaching a point of equilibrium in its population, although a continuing trend toward increased numbers of high-rise apartments could result in further significant growth in the population of the District.

Table 1. POPULATION OF POLITICAL JURISDICTIONS IN THE NCIAQCR, 1970

Jurisdiction	Population	% of total
District of Columbia	814,700	28
Montgomery County, Md.	520,719	18
Prince George County, Md.	657,710	22
Arlington County, Va.	173,104	6
Fairfax County, Va.	482,314	16
Loudoun County, Va.	36,349	1
Prince William County, Va.	109,310	4
Fairfax City, Va.	21,855	1
Falls Church, Va.	10,873	0
Alexandria City, Va.	108,841	4
	2,935,775	100

Source: Implementation Plan for controlling sulfur oxide and particulate air pollutants

There are 912,000 passenger car registrations in the NCIAQCR. The passenger car density is highest in the District of Columbia with 6,100 cars per square mile or nearly 14 times the average of 445 cars per square mile for the entire region.

Except for electrical power generation, there is no heavy industry in the region. Approximately 40 percent of the District of Columbia SMSA's population is employed by the government. The major industry is printing and publishing. Other industries in the area are electrical equipment; sone, clay, and glass products; and transportation equipment. Table 2 is a breakdown of employment categories of nongovernment employees; the largest categories are retail trade and services.

Table 2. NONGOVERNMENT EMPLOYMENT IN THE DISTRICT OF COLUMBIA

Employment category	Nongovernment employees	% of nongovernment	% of total
Manufacturing	53,000	7.2	4.3
Agricultural services, forestry, fisheries	2,000	0.3	0.2
Mining	4,000	0.5	0.3
Contract construction	19,000	2.6	1.6
Transportation and other public utilities	53,000	7.2	4.3
Wholesale	47,000	6.4	3.8
Retail	185,000	25.0	15.0
Finance, insurance, real estate	76,000	10.3	6.2
Services	244,000	33.0	19.8
Unclassified	56,000	4.5	4.5
Total	739,000	100	60

Source: Journey To Work, U.S. Census Department, 1970.

The city of Washington proper has been chosen as the area under study in this report. Issues such as emissions, urban activity factors, air quality trends, and meteorological influences will be dealt with primarily as they occur within the boundaries of the District of Columbia.

AIR QUALITY LEVELS AND TRENDS

The nine hi-vol monitoring sites operating during 1974 are located on the map in Figure 2 with alphabetic codes used throughout this report. Figure 3 presents the annual mean TSP concentrations measured; two center-city sites, NASN and CAMP, exceeded the national primary standard, while the other seven sites had levels in the fifties and sixties.

The trend in TSP levels has been generally downward for the last several years, as seen in Figure 4, although 1974 did show a general increase of a few $\mu g/m^3$ over 1973 levels. The longer-term trend, as recorded at the NASN site (Figure 5), shows a gradual decrease from levels of about 120 $\mu g/m^3$ in the late 1950's to the present levels of about 80 to 90 $\mu g/m^3$.

The District has adopted more stringent short-term ambient standards than the national ones. National primary and secondary 24-hour standards for total suspended particulate are 260 and 150 $\mu g/m^3$, respectively; District of Columbia standards are 160 and 140 $\mu g/m^3$. Both TSP standards have been consistently exceeded at the CAMP site since at least 1971 — an average of 15 percent of the time (see Table 3). The other stations exceeded the District primary standard during a few of the sampling periods each year since 1971 (up to 7 percent at the NASN site, near the CAMP site in downtown Washington).

Curiously, although the mean at the various sites shows a general downward trend over the 4-year period since 1971, the frequency of short-term standard violations has increased as seen in Table 3.

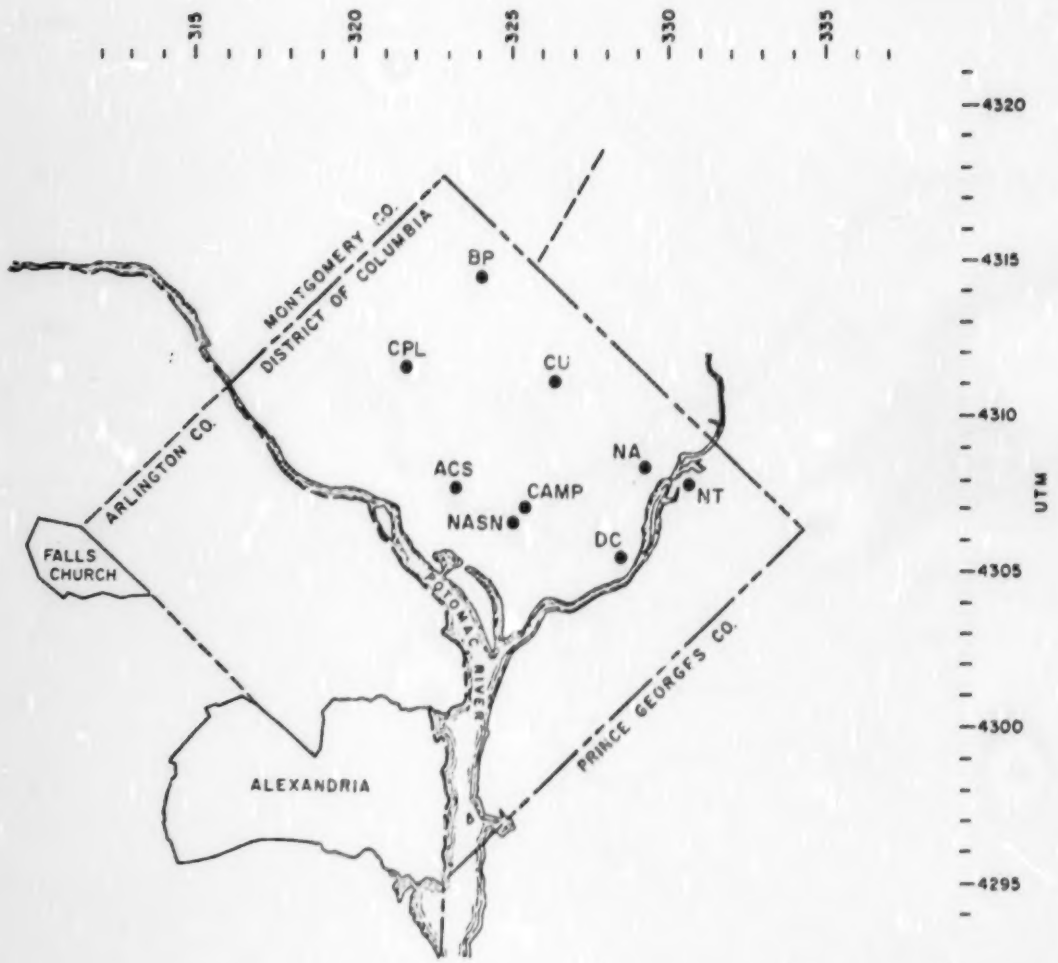


Figure 2. District of Columbia hi-vol monitoring network

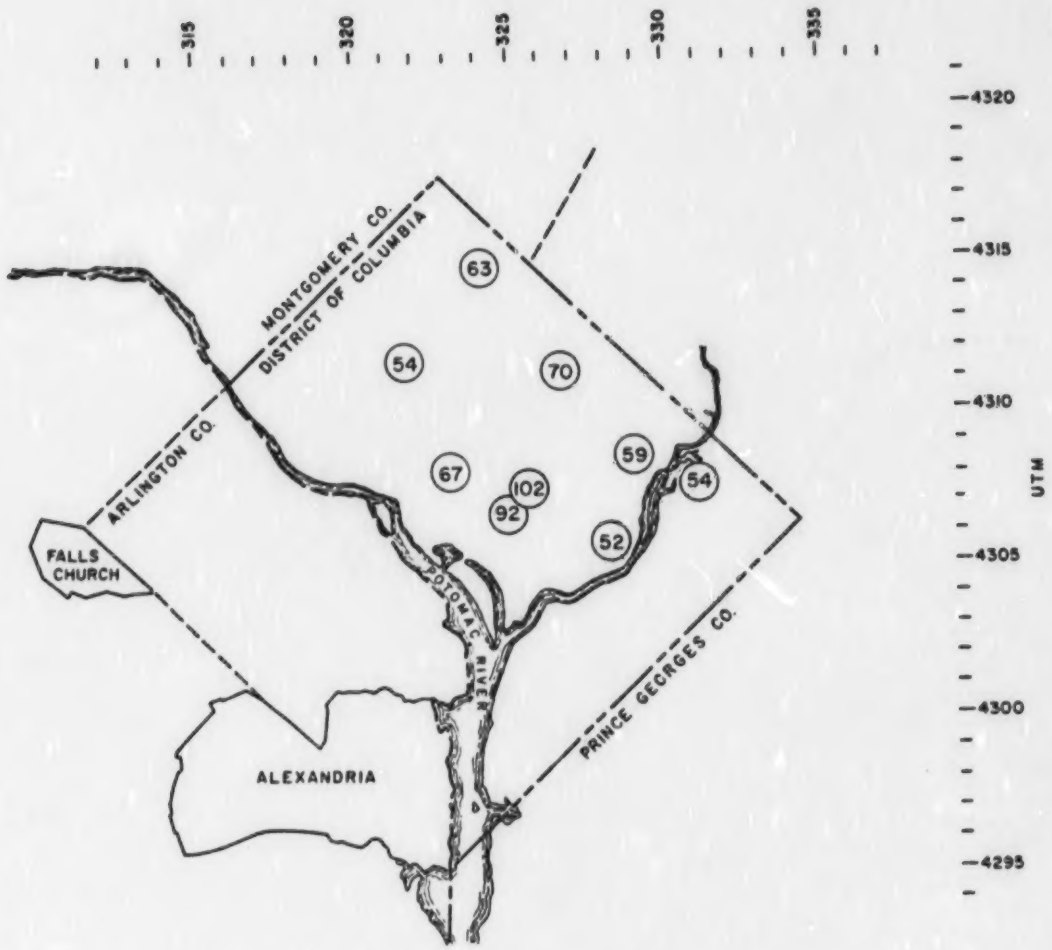


Figure 3. 1974 geometric mean TSP levels

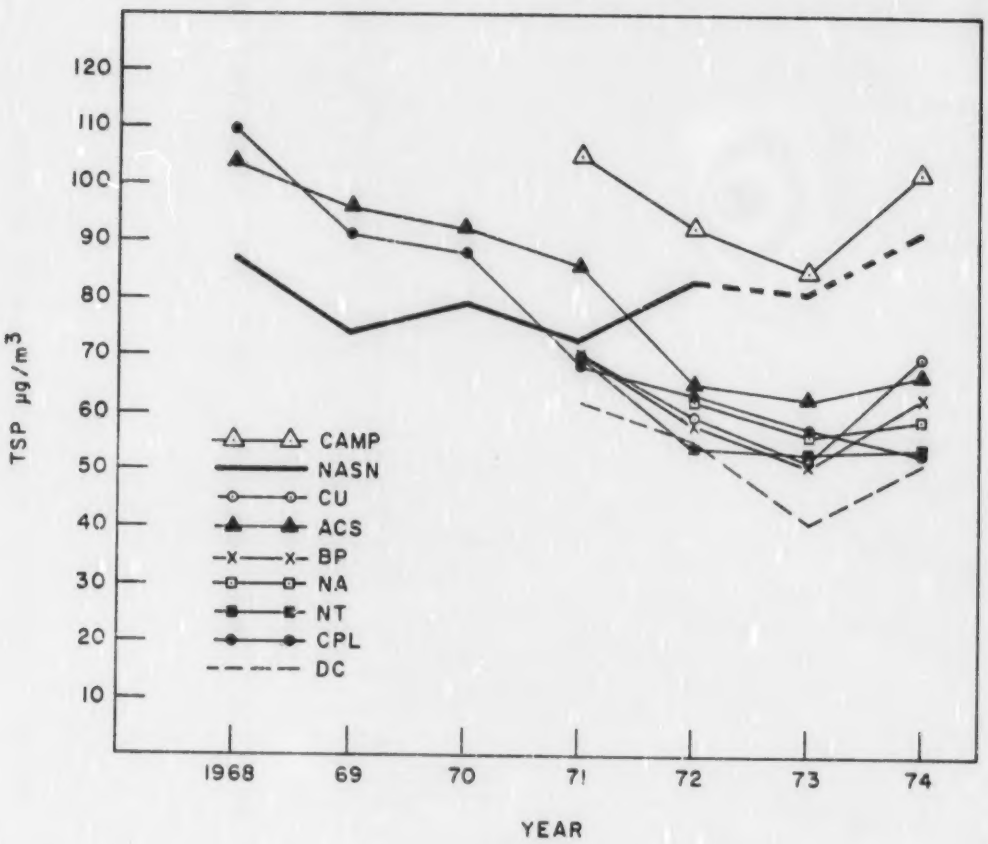


Figure 4. Trends in annual mean TSP levels

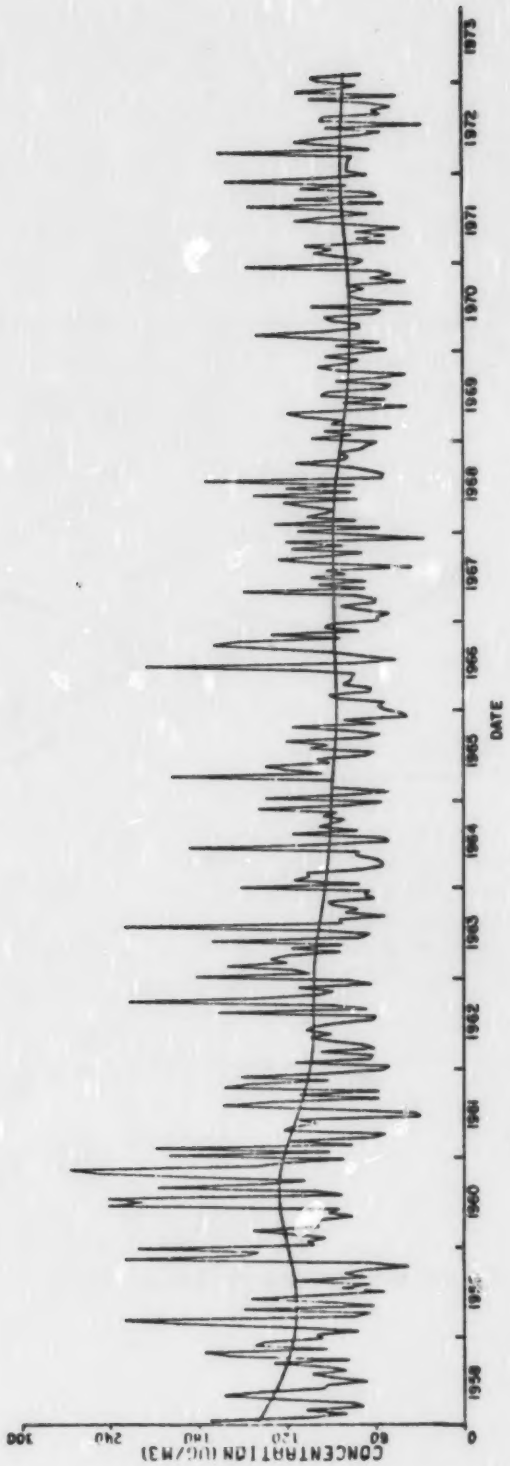


Figure 5. Smoothed trend in TSP levels at NASN site

Table 3. PERCENTAGE OF SAMPLES EXCEEDING 24-HOUR PRIMARY STANDARD

Map code	Address	% of times samples exceeded primary standards D. C. (160 $\mu g/m^3$) Federal (260 $\mu g/m^3$)				1974 annual geometric mean TSP $\mu g/m^3$
		1971	1972	1973	1974	
CAMP	CAMP Station 427 N. J. Ave. NW	13/1	11/5	17/2	18/6	102
NASN	Municipal Center 301 Indiana Ave. NW	0/0	7/0	6/0	7/0	92
CU	Catholic University 620 Michigan Ave. NE	1/0	0/0	1/0	1/1	70
ACS	American Chemical Society M & 16th St. NW	4/0	1/0	0/0	4/2	67
BP	Brightwood Police Station Georgia & Peabody NW	0/0	0/0	4/0	6/2	63
NA	National Arboretum 24th & R St. NE	-	4/0	4/0	6/5	59
CPL	Cleveland Park Library Conn. & Macomb NW	3/0	0/0	1/0	1/1	54
DC	D. C. General Hospital 19th & Mass. Ave. SE	0/0	0/0	2/0	2/1	54
NT	Neval Thomas School Anacostia & Grant NE	2/0	6/0	4/0	3/1	52

SECTION II

ANALYSES

In this section, the factors which might be expected to affect TSP levels in Washington, D.D., are considered. Analyses included are: sources and emissions, regulations and enforcement, meteorology, urban activity factors, and network design and monitor siting.

SOURCES AND EMISSIONS

An institutional city with no significant industry and a relatively mild climate, Washington's particulate emission levels are relatively low. Estimates for 1973 compiled by the District agency and the Council of Governments total about 7,200 tons per year in the District and nearly 32,000 tons per year in the entire AQCR. The average emission density for the District is 108 tons per year. As seen in Table 4, three-fourths of the D.C. emissions are from stationary source fuel use, both point and area sources, with half of that portion being attributed to the public utility power plants. The industrial process and refuse disposal emission categories are both insignificant in the District, but are less so in the entire AQCR -- there are sizable industrial process emissions in the Virginia portion, and large incinerators in both Maryland and Virginia.

Comparison of the present (1973) inventory with the 1969 compilation utilized in implementation planning provides some information on changes or trends in emissions, although differences in the manner of compiling and presenting the data make precise quantitative statements questionable.

Table 4. SOURCES OF PARTICULATE EMISSIONS IN WASHINGTON AREA - 1973

Source category	District of Columbia		NCIAQCR	
	Tons/year	Percent	Tons/year	Percent
Public utility fuel use	2,610	36		
Other point source fuel use	1,281	18	16,365	51
Stationary area source fuel use	1,569	22		
Transportation fuel use	1,498	21	8,435	26
Refuse disposal	116	2	1,717	6
Industrial processes	43	0	4,957	16
Miscellaneous	94	1	373	1
	7,211	100	31,847	100

The 1973 District of Columbia total of 7,211 tons per year represents a 64 percent reduction from the 1969 estimate of 20,050 tons per year.

As seen in Table 5, the major share of this large estimated reduction is attributed to the near elimination of emissions from refuse disposal and substantial reductions in governmental, commercial, and residential fuel use. The reduction in emissions from solid waste disposal has resulted from the almost total banning of small incinerators and the replacement of older municipal incinerators amd dumps with a well-controlled Solid Waste Recycling Center. The reason for the reduction in emissions from residential fuel use is less well documented; there has unquestionably been a significant change in the pattern of fuel use, but it is possible that differences in the nammer of compiling the emission inventories is also partially responsible.

Estimated emissions in the suburban areas have also decreased, although significantly less than in the District; the Maryland and Virginia portions of the AQCR have experienced estimated emission reductions of 32 and 27 percent, respectively. Consequently, sources in the District (with 28 percent of the AQCR population) now account for only 23 percent of the total estimated emissions in the AQCR, in comparison with 36 percent in the 1969 inventory. The pattern in emissions reductions in the suburban portions is similar to that in the District. Significant reductions have occurred in the refuse disposal and fuel use categories, but since these two categories account for a smaller share of the total emissions in the suburbs, the overall effect is less. Table 6 is an overall summary tabulation of emissions in the AQCR similar to Table 5.

The relative contributions of various source types also changed from 1969 to 1973 as a consequence of the reductions in some categories. As seen in Table 6, transportation fuel use, for instance, has decreased slightly, but still represents twice the relative proportion that it did in 1969.

Table 5. CHANGES IN PARTICULATE EMISSIONS IN DISTRICT FROM 1969 TO 1973

Source category	1969 (NAPCA)	1973 (D.C.)	Reduction 1969-1973	
			ton/year	percent
Stationary source fuel combustion:				
Power plants[a]	3,457	2,610	847	25
Other point sources	5,197	1,281	3,916	75
Area sources	4,970	1,569	3,401	68
Transportation fuel use	1,932	1,498	434	22
Refuse disposal				
- point	3,029	116	2,913	96
- area	1,465	0	1,465	100
Industrial processes	0	43	-43	-
Miscellaneous	-[b]	94	-94	-
Total	20,050	7,211	12,839	64

[a]Public utilities only.

[b]Not estimated.

Table 6. EMISSIONS SUMMARY FOR NCIAQCR

	District			Maryland			Virginia			Total AQCR		
	1969	1973	Reduction (%)	1969	1973	Reduction (%)	1969	1973	Reduction (%)	1969	1973	Reduction (%)
Stationary source fuel combustion												
- Point sources[a]	8,654	3,891	55	8,407	5,948	29	4,059	3,269	20	21,120	13,108	38
- Area sources	4,970	1,569	68	2,224	872	61	2,144	816	62	9,338	3,257	65
Transportation fuel use	1,932	1,498	22	3,999	3,929	2	3,347	3,008	10	9,278	8,435	9
Refuse disposal	4,494	116	97	3,102	840	73	3,905	761	80	11,501	1,717	85
Industrial processes	0	43	-	266	370	39[b]	3,592	4,544	26[b]	3,858	4,957	28[b]
Miscellaneous	-	94	-	-	178	100[b]	-	101	100[b]	-	373	100[b]
Total	20,050	7,211	64	17,998	12,137	32	17,047	12,499	27	55,095	31,847	42

[a] Including public utility power plants.

[b] Percent increase.

Similarly, the public utility electric power plants are presently the dominant stationary source category, as the government and commercial heating and power plants have reduced their emissions.

Table 7 (with Figure 6) presents a list of the major point sources, ranked by their 1973 emissions, indicating the change since the 1969 inventory. One obvious fact apparent in the table is that there are not large numbers of major point sources causing the particulate problem in Washington. Seven sources emitting over 100 tons/year account for 69 percent of the 5460 tons/year fuel combustion total, and the largest one — the major power plant in the District — alone accounts for 41 percent.

The cause of the observed changes in emissions are reasonably well established. As noted previously, the decrease in refuse disposal emissions was directly attributable to regulations requiring the replacement of all but multiple chamber small incinerators and placing a grain-loading restriction on larger units. This resulted in the elimination of four large municipal incinerators and one dump (Table 7), and the elimination of about 350 single chamber and about 550 flue-fed incinerators.

The decrease in fuel combustion emissions has apparently been caused by changes in the type of fuel used in the area. While details on a year-by-year, source-by-source, basis were not available, published information documents show clear on-going trends in fuel use, as tabulated in Tables 8 and 9. Table 8 shows a change toward cleaner fuels for residential use between 1950 and 1970. Coal usage decreased by 89 percent, while oil use increased by 48 percent; gas use increased by 131 percent to account for 55 percent of the total number of households in 1970. This trend in home heating from coal and oil to gas and electricity (Table 8) is typical of the Eastern U.S. and has most likely continued since 1970. In the case of industrial and power plant usage (Table 9), the trend toward cleaner fuels is also obvious. The use of coal decreased

Table 7. CHANGE IN MAJOR POINT SOURCE EMISSIONS, WASHINGTON, D.C.

Point source type	Particulate emisssions tons per year		% Change 1969-1973
	1969[a]	1973[b]	
Electric power	2700	2230	- 17
Military	3205	405	- 87
Electric power	754	380	- 50
Heating	80	270	+238
Heating	149	259	+ 74
Solid waste recycling	-	116	-
Heating	350	102	- 71
Hospital	860	58	- 93
Military research	11	49	+345
Hospital	44	46	+ 7
University	33	31	- 6
Hospital	18	29	+ 61
Hospital	22	22	0
Hospital	11	22	+100
Military	26	19	- 27
Military	18	19	+ 6
University	15	19	+ 3
University	7	13	+ 46
Incinerator	1042	-	-100
Incinerator	958	-	-100
Incinerator	736	-	-100
Incinerator	193	-	-100
Dump	120	-	-100
Housing	109	-	-100
Zoo	47	-	-100
Construction industry	40	-	-100
Housing	18	-	-100

[a]Source: NAPCA Emission Inventory - 1969.

[b]Source: D.C. Bureau of Air and Water Quality Control - 1973.

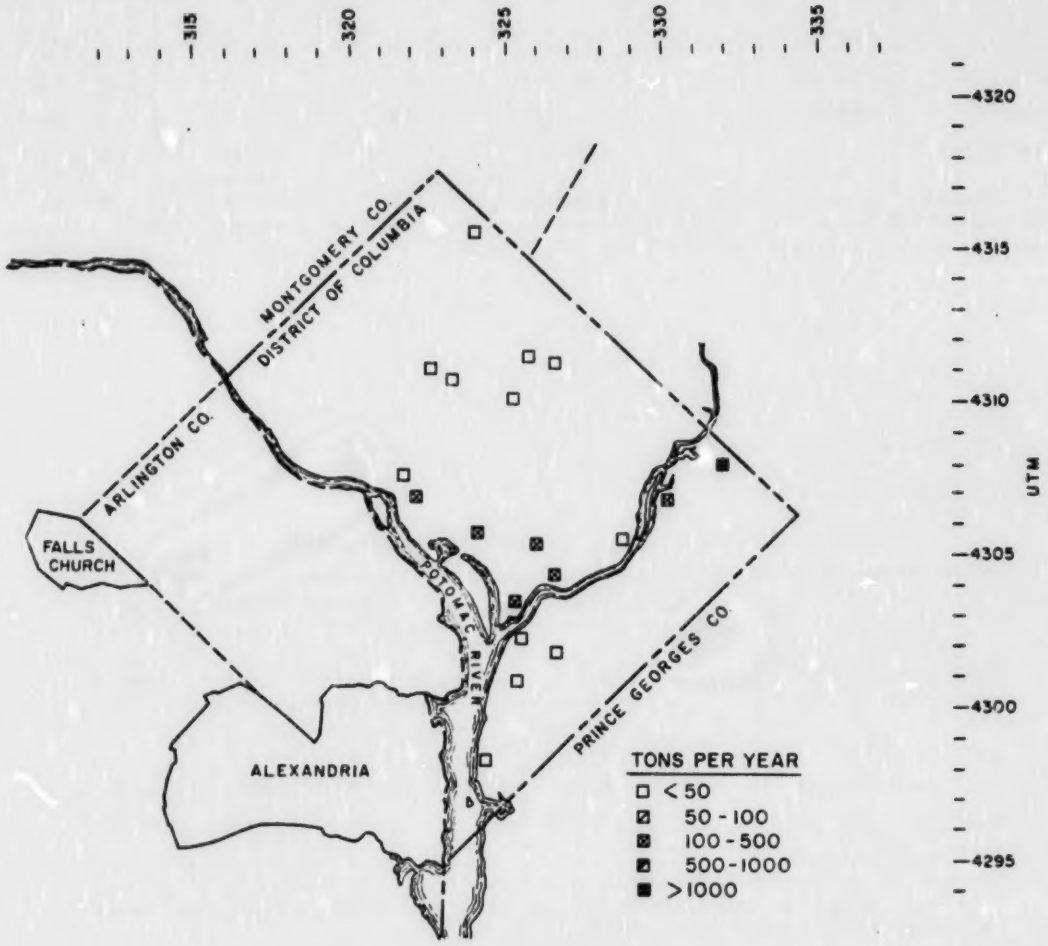


Figure 6. Location of major point source emissions

Table 8. 1950-1970 RESIDENTIAL FUEL USAGE BY NUMBER OF DWELLING UNITS IN WASHINGTON, D.C.

Fuel	1950	1960	1970	Δ1950-1960 as % of 1950	Δ1960-1970 as % of 1950	Δ1950-1970 as % of 1950
Gas	61,345	94,930	142,014	+ 55	+ 77	+ 131
Oil	61,755	105,722	91,727	+ 71	- 23	+ 48
Coal	88,070	48,227	9,977	- 45	- 43	- 89
Electricity	185	982	15,287	+430	+7,732	+8,455
Total	211,355	249,911	259,005	+ 18	+ 4	+ 22

Source: U.S. Census of Housing, 1950, 1960, 1970.

Table 9. FUEL USAGE TRENDS IN WASHINGTON, D.C.

		Industrial usage[a]			Electric utility usage[b]		
Fuel	(Unit)	1963	1972	%Δ 1963-72	1964	1973	%Δ 1964-73
Gas	10^6 ft^3	943	1,900.0	+101	-	-	-
Oil	1,000 bbl	307	183.8	- 40	20	5307	+264
Coal	1,000 tons	C	.2	-	293	240	- 18
Coke	1,000 tons	-	C	-	-	-	-

[a]Source: Census of manufacturers, 1963 and 1972. Fuels and electric energy consumed (data is for SMSA level).

[b]Source: Steam Electric Plant Factors book, 1965 and 1974, National Coal Association, Washington, D.C. (data is for city level).

[c]Statistically invalid.

drastically since 1960, and the use of oil and gas, cleaner fuels in terms of particulate emissions, increased between 1963 and 1973. Coal use in electric power production decreased by 18 percent and oil use increased by 264 percent between 1964 and 1973.

The underlying causes of the change in fuel use patterns are varied. Although a similar trend has been observed in most of the Eastern U.S., based on economic and convenience factors, air pollution control measures have also had a specific effect in Washington. The pollution control efforts, beginning in the late 1960's were aimed more at reducing SO_2 than TSP, but did result in a significant impetus toward cleaner fuels, reducing emissions of both pollutants. The seasonal pattern of TSP levels is shown for the NASN site in Figure 7. Although the pattern is erratic, as is typical of TSP, there is a noticeable change from high winter-low summer patterns in the 1950's and early 1960's to a reversed pattern with higher summer levels since the late 1960's.

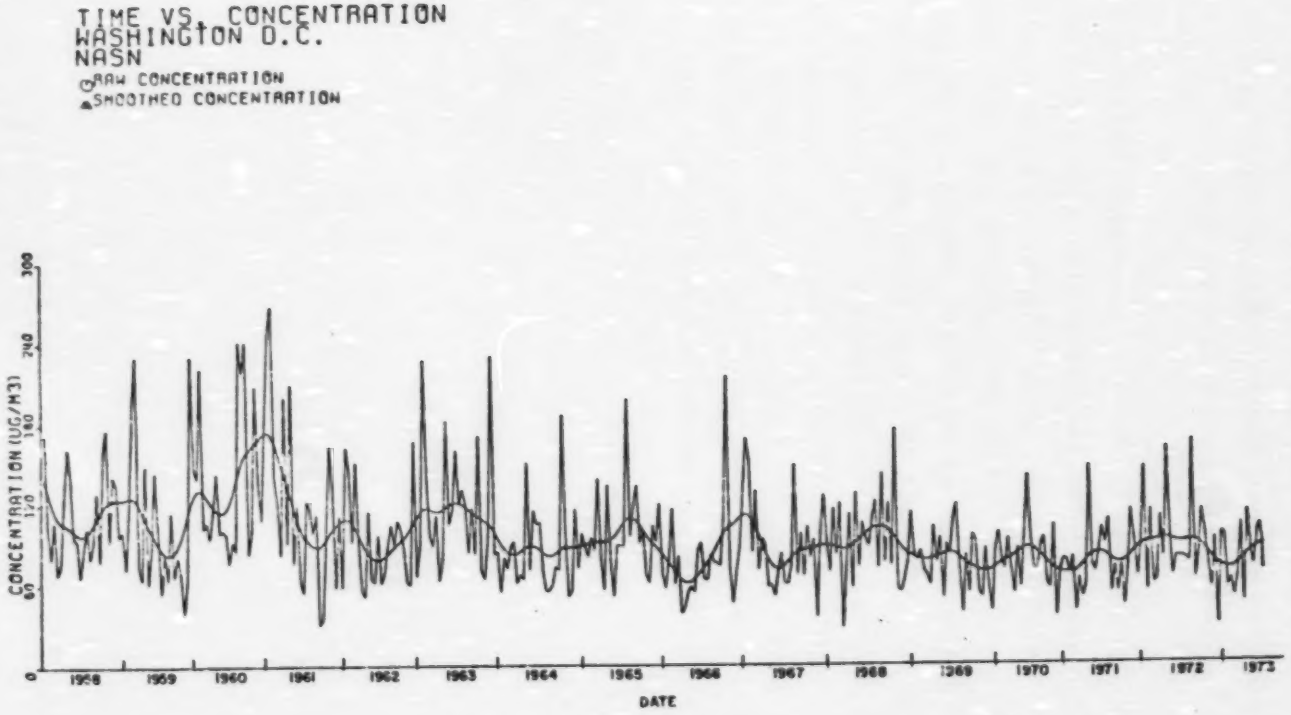


Figure 7. TSP trends at NASN site

METEOROLOGY/CLIMATOLOGY

Several meteorological factors were investigated for possible influences on TSP levels in Washington, D.C.: precipitation, degree days, and wind direction. While total clear-cut relationships will not be found, because suspended particulate levels are the result of more than one influence at a time, meteorological factors can be expected to have some discernable effects. In particular, since the increase in TSP levels between 1973 and 1974 was so widespread over the city, a meteorological contribution to that effect seems plausible.

In general, TSP-meteorology comparisons can be made in terms of either annual averages of long term trends or seasonal patterns of monthly levels of the various parameters. Long term TSP data is available only from the NASN site, data since 1968 is available from two other sites, and only 4 years of air quality data is available for city-wide comparisons (Figures 4 and 5). The seasonal patterns of TSP levels during 1974 are summarized in Figure 8. Data from the NASN site is omitted, and part of that from the CAMP site dashed, because too few samples were collected to provide valid averages.

The long term mean precipitation in the Washington area is 39 inches, but amounts have been typically below this for 20 years, as seen in Figure 9. The trend in annual precipitation amounts has been increasing over the past 10 years; in the previous 10 years it remained generally constant and then decreased slightly between 1960 and 1965. Annual precipitation decreased in 1973 and 1974 to 36 inches in 1974. One might expect an inverse relationship between rainfall and particulate levels, but TSP trends over the entire period do not follow precipitation trends closely. Long term data is only available for the NASN site, Figure 5, at which there is a general decrease in TSP from 1958, and a stabilization from 1966 to 1973. The generally-increasing precipitation from 1965 through 1972 matches in part the general decrease in TSP from 1968 onward, but the

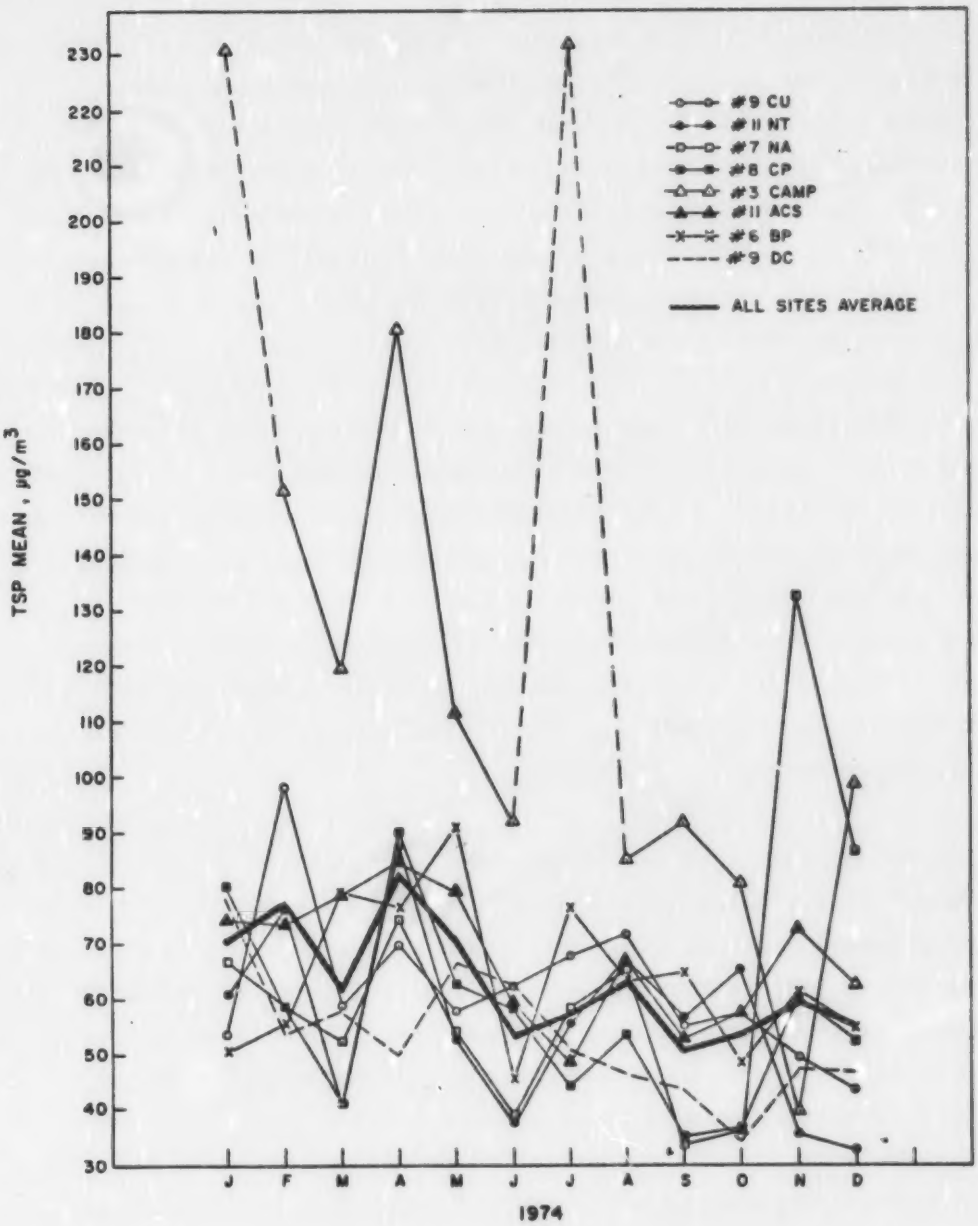


Figure 8. 1974 Seasonal pattern of monthly TSP levels

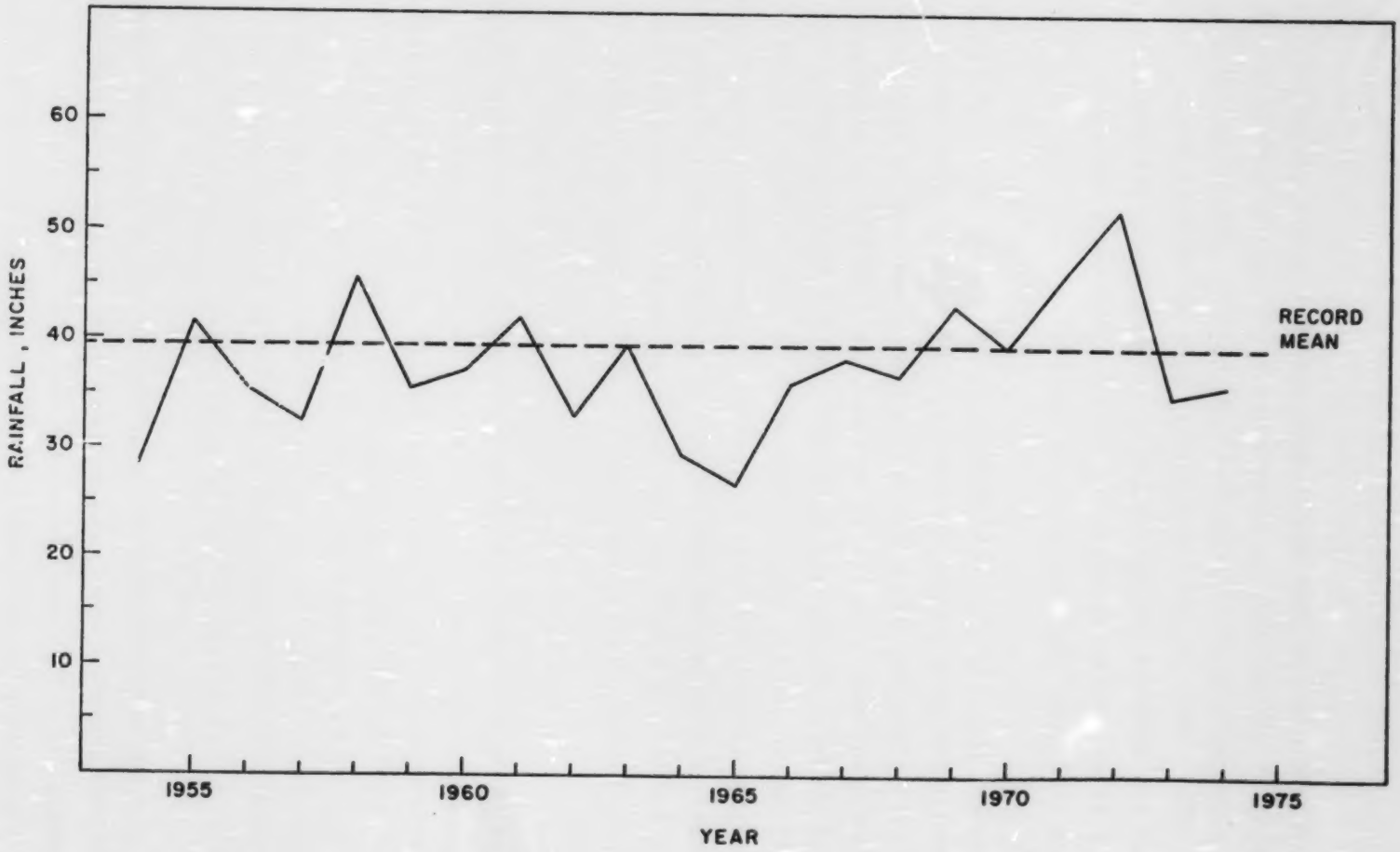


Figure 9. Trend in annual rainfall

abrupt decrease in rainfall in 1973 and 1974 is not reflected very precisely in TSP levels; the clear pattern for all the Washington, D.C. sites is a decrease in TSP levels from 1971 to 1973, and a distinct increase in 1974. Thus, on the basis of this type of analysis alone, it is clear that the observed TSP trends are not predominantly the result of precipitation trends, though a significant influence, operating in conjunction with other factors, is quite possible.

Seasonal patterns of precipitation and TSP levels show somewhat more correlation (see Figures 10 and 11). TSP levels are inversely related to precipitation, except during the summer months. In 1974 there was a drier than usual July – 1.15 inches of rain in 1974 versus a norm of 4.12 inches. October was also drier, with 1.13 inches versus the norm of 2.66 inches for the month. The number of days on which precipitation occurred in 1974 followed the pattern of precipitation amount; July and October had fewer than average days with precipitation (Figure 10). August has a much larger than average number of days with precipitation, but the total rainfall was typical, and TSP levels did not decrease during this month.

Thus, February, April, and October, November were the driest months of 1974 in terms of both inches of precipitation and number of days with precipitation. The average city-wide TSP level increased in April, July, and October-November, suggesting that precipitation might be a significant factor in determining short-term average particulate levels. An analysis of daily precipitation versus rainfall would prove useful in this effort; however, the monitoring sites in Washington do not sample daily, and hence do not provide an adequate data base.

Wind speed averaged somewhat lower than normal in 1974, with January and July somewhat lower, and November a little higher than the norm (Figure 12). TSP levels generally decrease through the year; wind speed decreases only in the summer. Windspeed was particularly reduced during

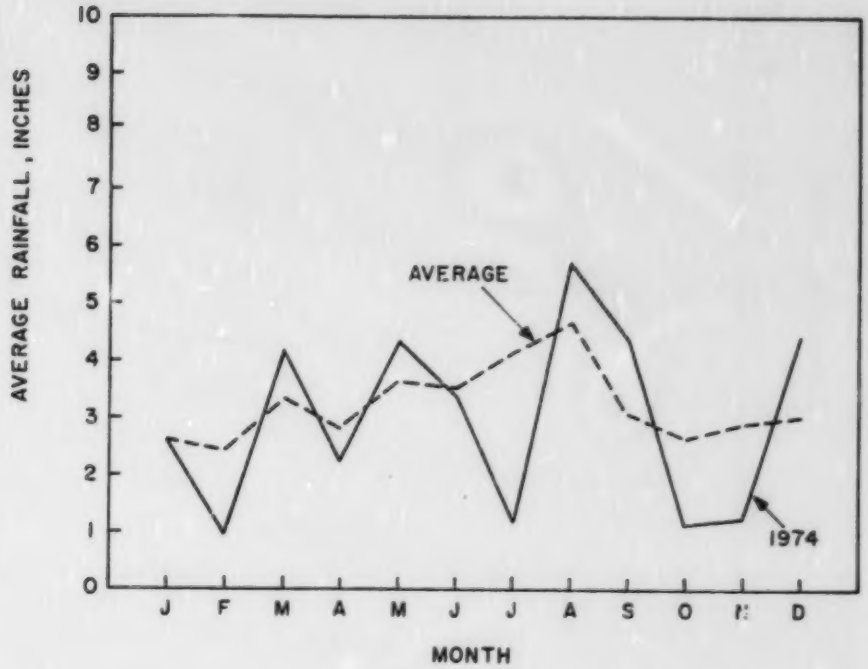


Figure 10. Seasonal pattern of precipitation amount

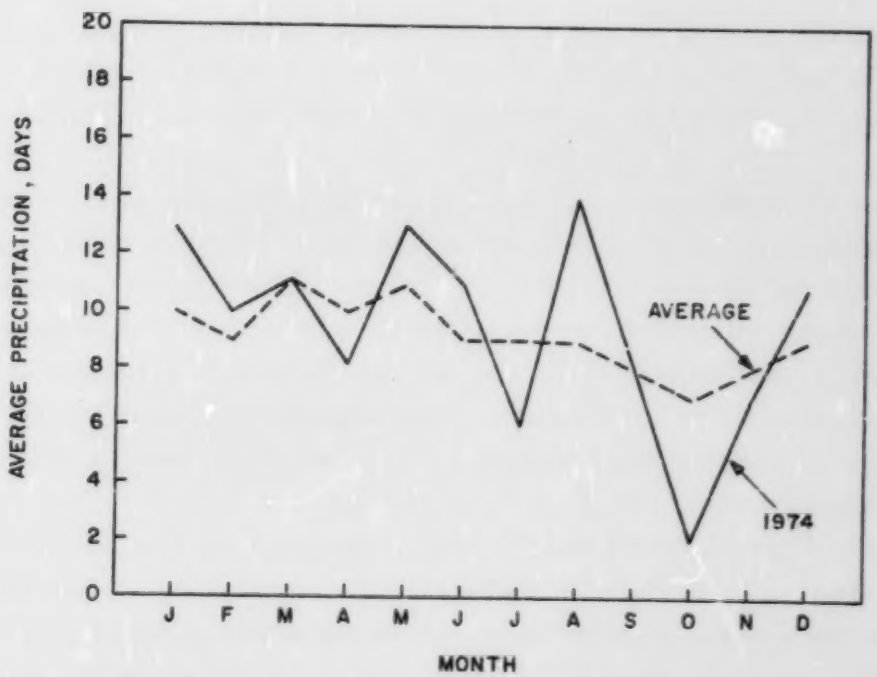


Figure 11. Seasonal pattern in days with precipitation

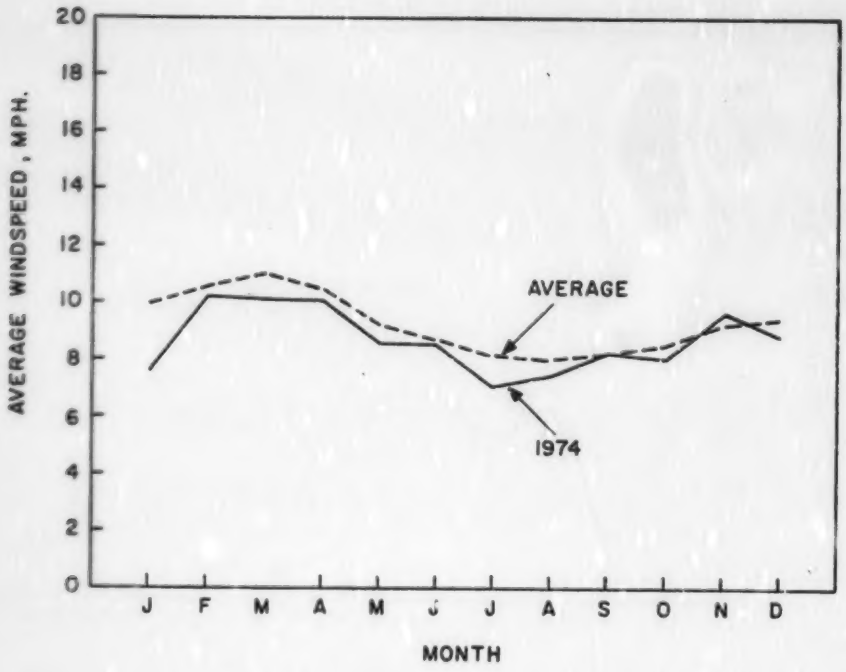


Figure 12. Seasonal pattern in average windspeed

April and July, which are also months that had less precipitation and higher TSP levels. Again, the impact of meteorological parameters seems to be in contributing to the short-term fluctuations in TSP levels.

It is of course also likely that wind direction could be an influential meteorological factor, at least at specific locations. Winds are most often from the south to southwest and the northwest, as reported at Washington National Airport. A summary of the wind directions on sampling dates at the Catholic University monitoring site is presented in Figure 13 as an example; it has wind direction frequencies typical of the full year's data. On days on which particulate samples were taken, winds came mostly from the south-southwest — 32 percent from 180° to 230° — and the northwest — 23 percent from 310° to 350°. This pattern is fairly typical of the eastern U.S.; the northwesterly winds occur primarily in the winter, with the passage of cold fronts, while the southerly winds occur primarily in the summer, because of the general circulation around the Bermuda high.

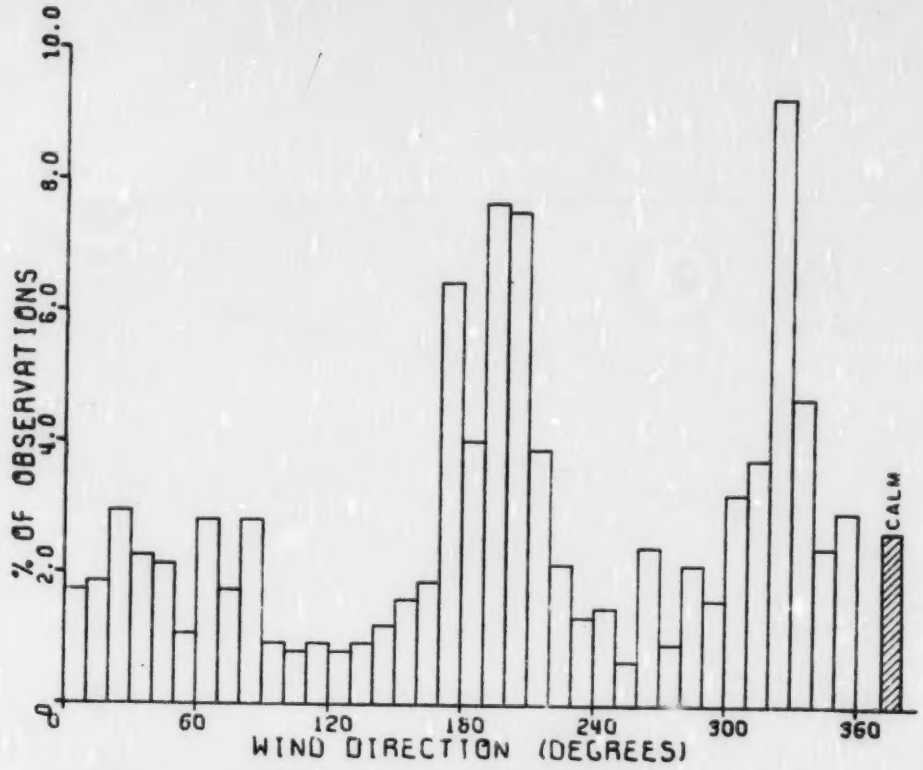


Figure 13. Wind direction frequencies on sampling days at Catholic University site

Washington has a long-term average of 4211 heating degree-days per season. As seen in Figure 14, winters were typically colder than average through most of the 1960's, and then became significantly warmer since the 1970-1971 season. This trend is roughly comparable to the long-term TSP trend at the NASN site (Figure 5), and since space heating is a significant portion of the emissions inventory, it is possible that a portion of the observed pattern is attributable to the differences in heating demand. The 1974 seasonal pattern in Figure 15 indicates that both January and December were warmer than usual; both were also relatively lower in TSP levels than adjoining months, which contributes to the suggestion of an effect of heating load.

The 1973-1974 value of 3596 degree-days is 14.6 percent below the long-term average of 4211, and is 21.2 percent below the 1969-1970 maximum of 4565 degree-days, so that an effect amounting to several percent is not at all unreasonable.

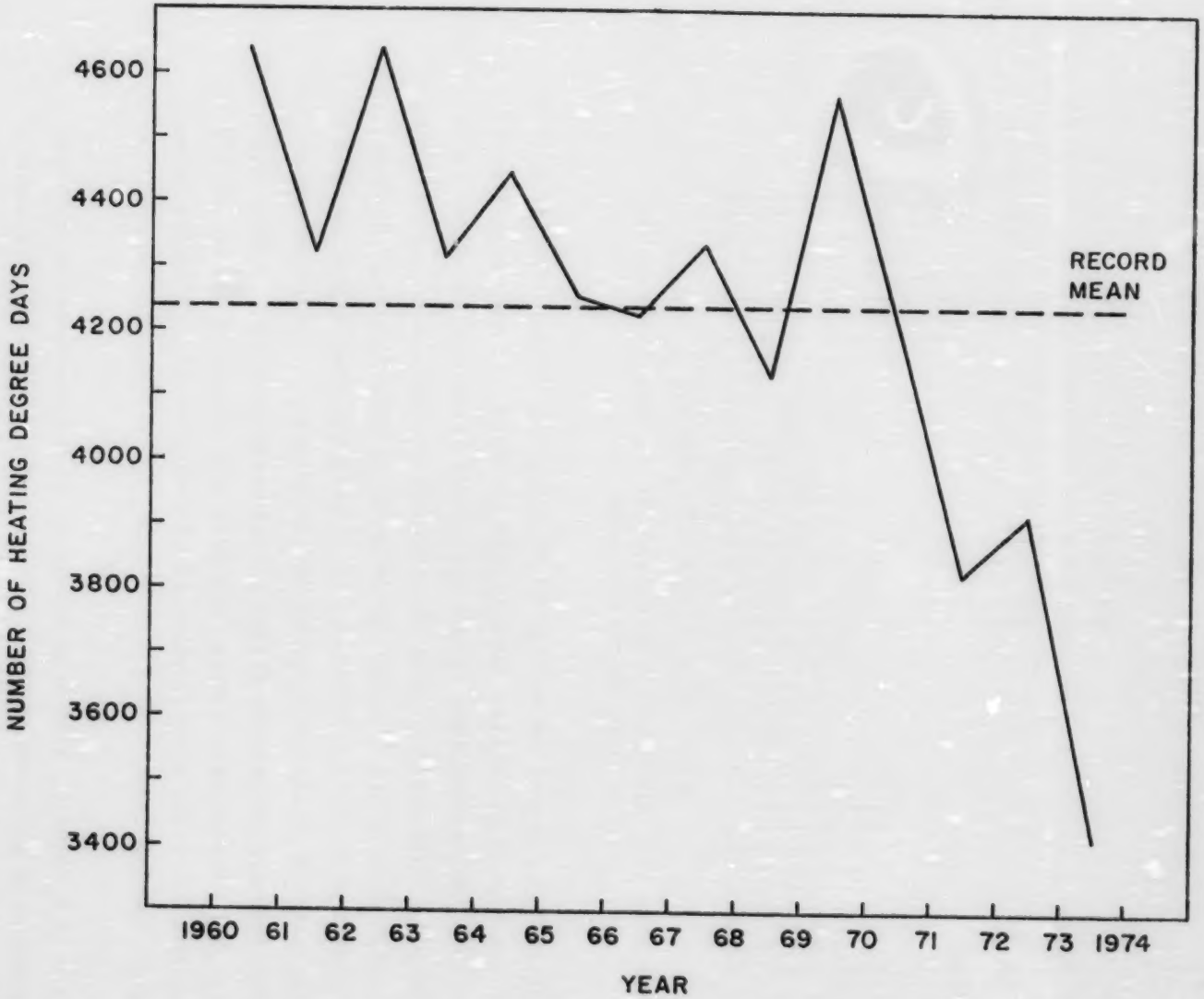


Figure 14. Seasonal trend in heating degree-days

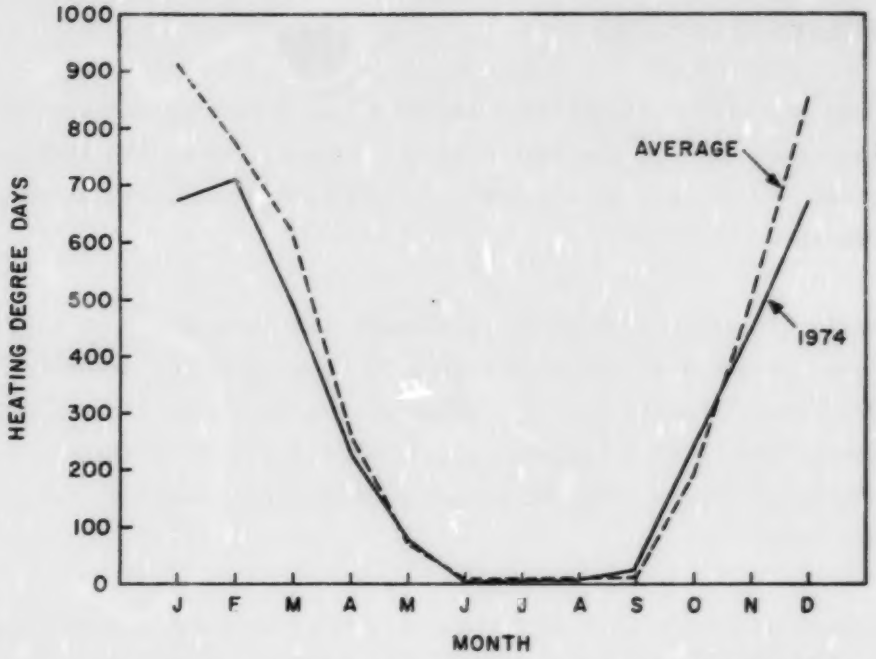


Figure 15. Seasonal patterns in heating degree-days

URBAN ACTIVITY FACTORS

Because major industrial sources are nonexistant in Washington, and large fuel-burning installations are very few in number, increased concern must necessarily center on categories of sources that are more disperse in nature and generally less prominently involved in traditional pollution control planning. Two such categories that appear to be of significant concern in Washington are emissions from construction activity and traffic-related emissions. Note that these categories do not appear in the emission inventory, with the exception of exhaust emissions from transportation sources; the fugitive dust emissions from traffic movement and construction activity are excluded (as they are in almost all current emission inventory efforts).

Construction Activity

There has been a significant amount of construction activity in the Washington area in the last 2 years; in particular, the METRO transit system development is a source of construction activity of various types throughout the city.

Nearly all sites in Washington (except the Cleveland Park Library) had higher annual mean TSP levels in 1974 than in 1973. According to the 1974 "Annual Report on the Quality of the Air in Washington, D.C.," subway construction influenced particulate levels at three sites: Brightwood Police Station, Catholic University, and D.C. General Hospital (see Figure 16).

Brightwood Police Station is nearly a mile from the transit system's Glenmont Route, generally to the west of the segments between the Takoma and Fort Totten stations. Construction was begun along this part of the line in May 1973 and continued through 1974. As seen in Figure 17, particulate levels are not strikingly higher when the wind was blowing from the east; however, the broad sector encompassed by the various portions of the subway route makes it unreasonable to expect a truly clear cut effect in an analysis such as in Figure 17. The site did experience during that period a number of isolated unusually-high values, and a brief examination of daily meteorological records does indicate these tend to occur on days with airport winds from either the west-southwest or north, which is not inconsistent with a noticeable effect from the subway station construction sites.

The Catholic University monitor is located on the campus, about 600 yards from the Glenmont Line. The Brookland transit station site is almost directly east, and the line construction both north and south of the station extended through 1974; the segment to the southwest was begun in 1972. However, there is no elevated TSP concentration with winds from any particular direction as seen in Figure 18.

Figure 16. Subway system location map

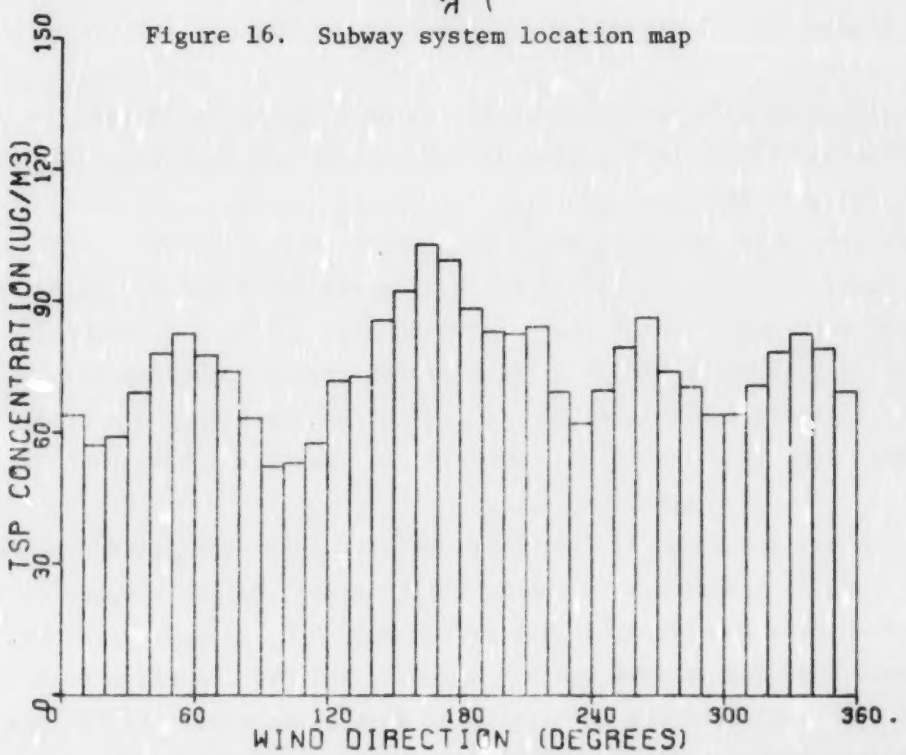


Figure 17. TSP versus wind direction at Brightwood Police Station site

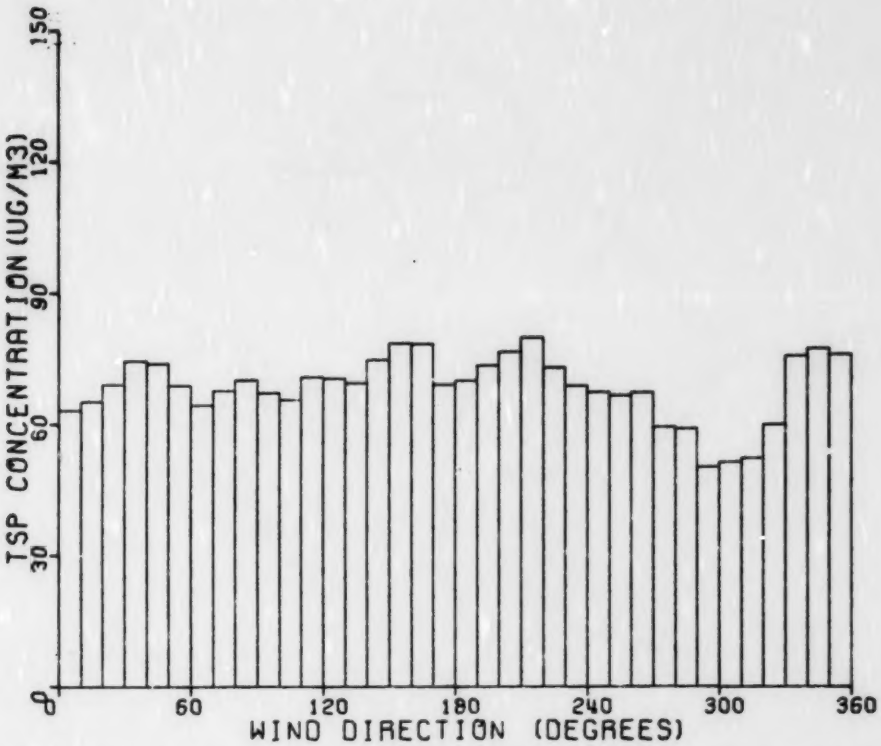


Figure 18. TSP versus wind direction at Catholic University site

The hi-vol at D.C. General Hospital is at a height of 40 feet, on top of a building within the hospital grounds, about 400 feet from a major roadway. In 1974 there was construction on the hospital grounds around the monitoring site building, but this construction was mostly at ground level. The Statium-Armory station of the New Carrollton transit line is located to the west-northwest of the monitoring site. Subway construction was begun on both sides of the Stadium-Armory station in March 1973. There is an indication of higher TSP concentrations from this direction (Figure 19), which could be the effect of the subway construction.

It does not appear as if the other outlying monitoring sites in Washington would be influenced by subway construction, either because of their distance from the lines or because the subway is being constructed with a tunneling method in some areas. However, the two CBD sites (CAMP and NASN) have been subjected for the last 2 or 3 years to a variety of construction, including much building construction as well as the many downtown portions

of the subway system. While there are almost surely other factors involved, it is probable that construction emissions are a significant part of why TSP levels at those two sites remain elevated.

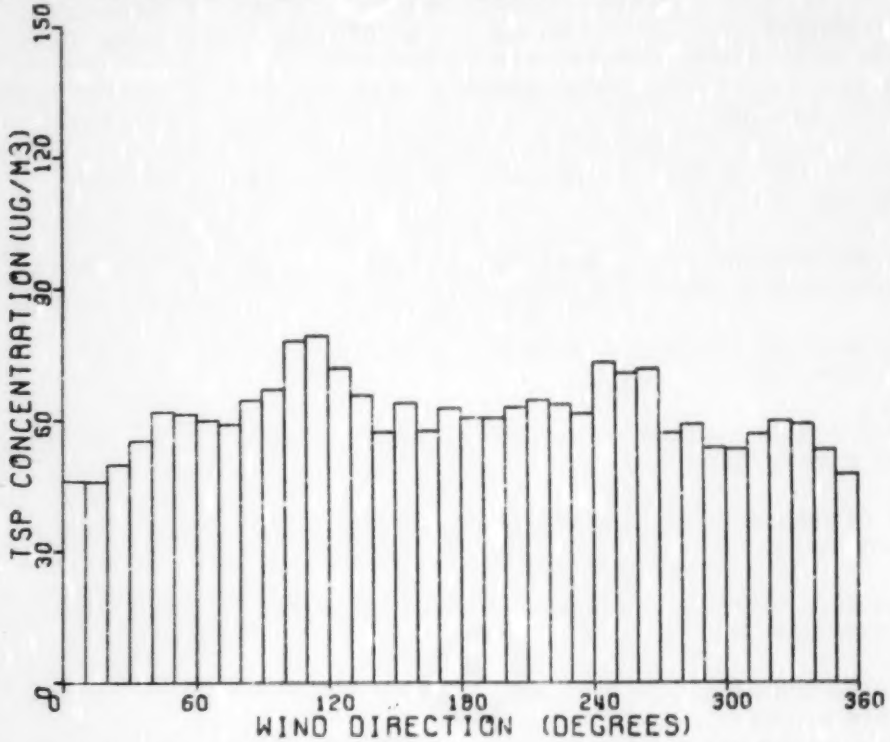


Figure 19. TSP versus wind direction at D.C. General Hospital site

Traffic-Related Emissions

Because of the relative lack of major stationary sources of TSP, it would be expected that traffic-related particulate matter, both tail pipe emissions and reentrained street dust, would be a major influence on measured levels. Hence an investigation was made, using traffic data obtained from the District Highway Department.

Table 10 includes the 1974 average daily traffic (ADT), an annual 24-hour average count of traffic in both directions, for the major road segment nearest each monitoring site. This has been normalized (by dividing by

Table 10. ANALYSIS OF AVERAGE DAILY TRAVEL VERSUS PLANT DISTANCE

Address	Street	ADT 1974 x 10^3	Ratio of ADT to slant distance	1974 annual geometric mean TSP
CAMP Station 427 N. J. Ave. NW	New Jersey	5.0	67	102
Municipal Center (NASN) 301 Indiana Ave. NW	Indiana	3.7	34	92
Catholic University 620 Michigan Ave. NE	Michigan	25.8	43	70
American Chemical Society M & 16th St. NW	M Street	5.2	49	67
Brightwood Police Station Georgia & Peabody NW	Georgia	25.8	206	63
National Arboretum 24th & R St. NE	Bladensburg	22.9	153	59
Cleveland Park Library Conn. & Macomb NW	Connecticut	31.3	481	54
Nevel Thomas School Anacostia & Grant NE	Anacostia Expressway	95.1	190	54
D.C. General Hospital 19th & Mass. Ave. SE	19th Street	8.9	22	52

slant distance) and plotted against annual mean TSP levels in Figure 20. Although this type of analysis has in other cities indicated reasonable relationships, it is clear from Figure 20 that TSP and ADT/slant distance are not well correlated in Washington.

There are apparently differing reasons at the various sites for this lack of relationship. Both the NASN and CAMP sites in the center city area had high particulate levels in 1974 but their ratio of ADT to slant distance is relatively low. It appears that construction near the CAMP site

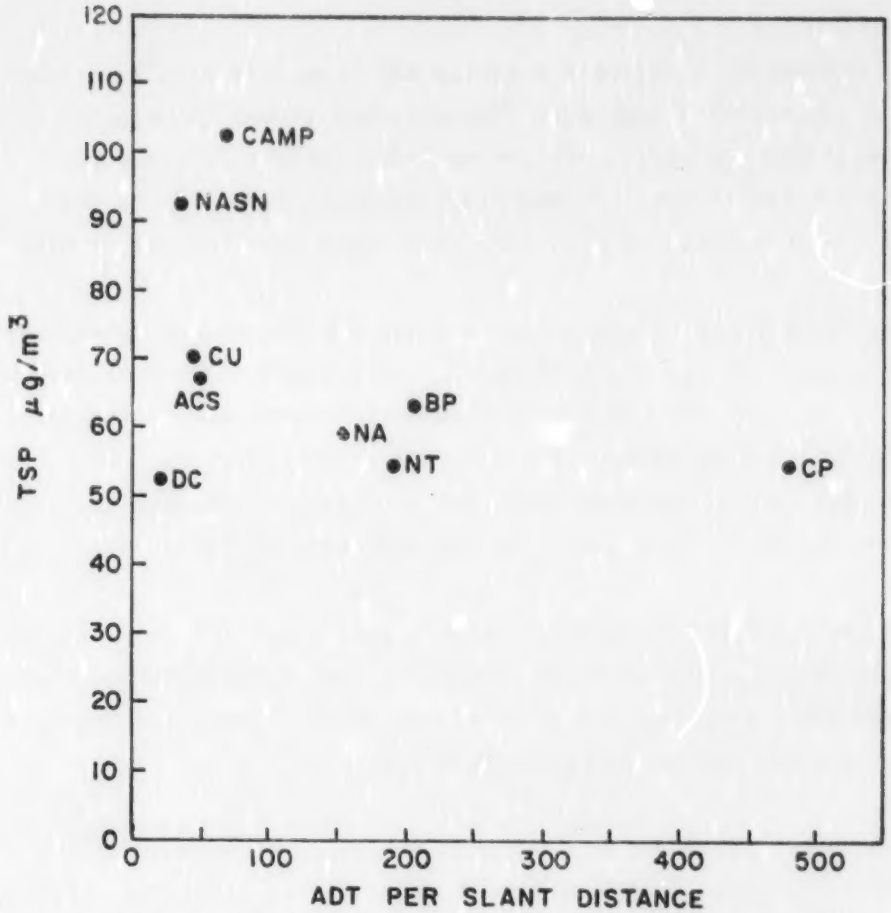


Figure 20. ADT per slant distance at Washington sites

may have not only increased the TSP levels, but also indirectly influenced the ratio because average daily travel on the nearest major roadway was very low, indicating that traffic may have been rerouted in the downtown area. On the other hand, the NASN monitor is 80 feet above street level, which would give it access to longer-range TSP influences that are unaccounted for in the ADT.

D.C. General Hospital has a low TSP level and a low ADT to slant distance ratio, and low ADT on the major street nearby. The site is nearly surrounded by construction and it is well away from the street (400 feet), so traffic must not be the major influence here, either.

The Catholic University site, with a medium TSP level (70 $\mu g/m^3$) is nearest to a major street with high ADT. However, the street (Michigan Avenue) is about 600 feet away, and the monitor's height is close to 50 feet, so the ratio is low. In addition, Michigan Avenue is to the southeast of the University, a direction from which the wind rarely blows.

Both the Brightwood Police Station and National Arboretum have relatively low mean TSP levels, 63 $\mu g/m^3$ and 59 $\mu g/m^3$, respectively. Their closest streets' ADT's are high and ADT to slant distance ratios are in the center of the range for Washington. The National Arboretum monitor is located in a park, on the ground, about 150 feet east of the street. The Brightwood monitor is 30 feet above and 120 feet east of the street.

The American Chemical Society monitor is well away from (100 feet high and 30 feet south of) a street in the center of town which nevertheless has a very low ADT. The ADT to slant distance ratio is low, and the mean TSP level is near the middle range (67 $\mu g/m^3$).

The Cleveland Park Library and Nevel Thomas School sites have low TSP levels for 1974 (54 $\mu g/m^3$), high ADT on the nearest well-traveled roadway, and relatively high ADT to slant distance ratios. The Cleveland Park hi-vol is 80 feet west of the street, while the Nevel Thomas monitor is about 500 feet from the expressway, which is the nearest major roadway, although the wind rarely blows from that direction.

The traffic patterns thus do not have a very great direct influence on the TSP levels measured at the existing sites. This is probably largely because the sites are not well-situated to measure traffic influence. All but two are either very low, very high, and/or at large horizontal distances from traffic and other activity.

NETWORK DESIGN AND MONITOR SITING

The National Air Sampling Network began monitoring in Washington, D.C. in 1958. In 1974 there were nine sites distributed fairly evenly around the City of Washington, in center city, suburban, residential, and commercial areas (there is no industrial area in the city). The height above ground of the monitors ranges from ground level (given as 3 feet) to the top of a tall downtown building (100 feet). There is a general freedom of air movement around the city; however, the air flow to individual monitors may be influenced by surrounding tall buildings or adjacent walls.

Table 11 describes land-use and particulate sources around the nine monitoring sites. In general, the sites are typical of urban networks, but the variety of placement is more extreme than in most cases.

The CAMP site is located on top of a one-story building in downtown Washington. Since it was moved there, there has been continual construction in the area with the result that at present it is nearly surrounded by tall office buildings, with the exception of the fire station to the north. The hi-vol is 75 feet from New Jersey Avenue. The placement of the taller buildings around it cancels any directional wind effects on suspended particulate readings.

The sampler at the National Arboretum rests directly on the ground, under 40 to 50 foot trees. It is in a park area, at a distance of about 150 feet from the nearest busy street. Its 1974 annual mean for TSP is among the lower ones, but not the lowest, despite the fact that it may be shielded and removed from some of the normal city sources of particulates. There was, however, construction of greenhouses nearby during the month of November, which may have brought the annual mean particulate level up (see Figure 5).

Table 11. LAND-USE AND PARTICULATE SOURCES SURROUNDING THE MONITORING SITES

GCA code	Address	1974 TSP geometric mean, $\mu g/m^3$	Land use
CAMP	CAMP Station 427 N.J. Ave. NW	102	Construction in surrounding area
NASN	Municipal Center 301 Indiana Ave. NW	92[a]	In downtown office area; construction SE
Cu	Catholic University 620 Michigan Ave. NE	70	Adjacent to residential and commercial areas; hospitals N, SW, W; influence of subway construction E, N
ACS	American Chemical Society M and 16th St., NW	67	In the midst of office buildings and hotels
BP	Brightwood Police Station Georgia & Peabody, NW	63	Adjacent to residential areas; possible influence of dirt trucking from subway construction 1 mile away
NA	National Arboretum 24th & R St. NE	59	Some construction near monitor during November
CPL	Cleveland Park Library Conn. & Macom NW	54	Adjacent to residential area (W); on heavily-travelled route (E)
NT	Nevel Thomas School Anacostia & Grant NE	54	Power plant and incinerator 1/2 mile W; highway 150, E
DC	D.C. General Hospital 19th & Mass. Ave. SE	52	Power plant NE 1/4 mile; stadium nearby; construction SW and SE; subway construction NW

[a]NASN site, sampling one in every 12 days.

The hi-vol at the Nevel Thomas School is set on the ground near the school, about 150 to 200 feet from an access lane adjacent to the Anacostic Freeway. The freeway seems to have little influence on particulate levels monitored at this site, probably because of the low frequency of wind from this direction. Peak TSP concentrations occur from the south, which could be the influence of the power plant to the south-southwest or of the wind channeling up the Anacostia River.

The hi-vol at the Cleveland Park Library is located on top of the building (about 25 feet high) which is set back from the street in a commercial street, adjacent to a residential area. It is the only site where TSP decreased from 1973 to 1974, but no apparent reason was found.

The ACS monitor is at a height of about 100 feet, the highest monitoring site in Washington, D.C. It is on a building in the downtown area with an adjacent 14-foot wall to the east, which would affect winds from that direction. The NASN site is also high, located on the top of an office building in the downtown area at a height of about 80 feet and 75 feet from a well-traveled street.

REGULATIONS AND ENFORCEMENT

Regulations

Regulations in the District of Columbia include limitations on the sulfur content in fuel oil and coal, nitrogen oxides, organics, sulfur oxides, odors and automobile exhaust. Also included are various policy and implementation regulations. The sections on fuel burning, incinerators, manufacturing processes, fugitive dust, and visible emissions are summarized below.

Fuel Burning - Particulate emissions are limited to 0.13 pounds per million Btu input for installations using less than 3.5 million Btu/hr input.

Emission standards for larger installations decrease, as pictured in Figure 21, a comparison of the Washington fuel combustion regulation with those in the other cities studied. The shaded area represents the mean of the regulations for the 14 cities, plus and minus one standard deviation.

Incinerators - Single chamber and flue fed incinerators are prohibited. Emissions from incinerators installed after the enactment of the regulations are limited to 0.03 grains of particulate matter per standard dry cubic foot of exhaust gas corrected to 12 percent carbon dioxide. After July 4, 1973 no incinerator existing at the time of enactment can be operated which is larger than 400 pounds per hour capacity or emits more than 0.08 grains per standard cubic foot of exhaust gas. No incinerator can be installed after July 11, 1975, unless no alternative disposal method exists.

Manufacturing Processes - The emissions limits, expressed in terms of a typical process weight curve, are pictured in Figure 22, in a manner similar to that of Figure 21. An additional restriction requires that after July 1, 1972, emissions cannot exceed 0.03 grains per standard dry cubic foot of exhaust gas, regardless of the weight of material processed.

Fugitive Dust - Reasonable precautions must be taken to prevent particulate matter from becoming airborne while being handled, transported or stored and during construction and demolition operations. Reasonable precautions include the use of water or chemicals during construction and demolition, the use of asphalt, water, oil or chemicals on surfaces liable to create airborne dust, the use of covers on open trucks.

Visible Emissions - No visible emissions are allowed, except for startup, cleaning, soot blowing and adjustment operation. The emissions in these instances cannot exceed 40 percent opacity except for 4 minutes in any 60 minutes or periods aggregating 24 minutes in any 24 hours.

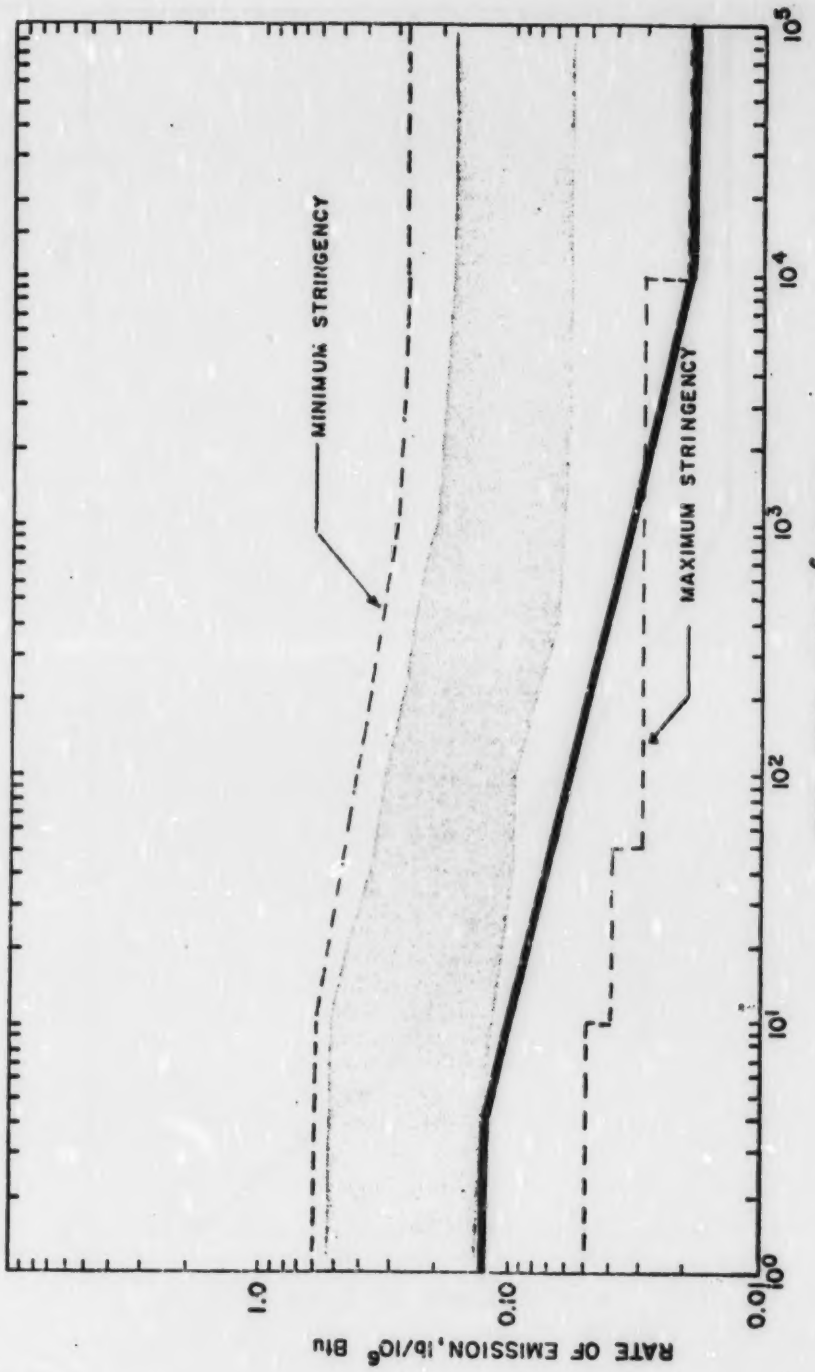


Figure 21. Fuel combustion emissions regulations

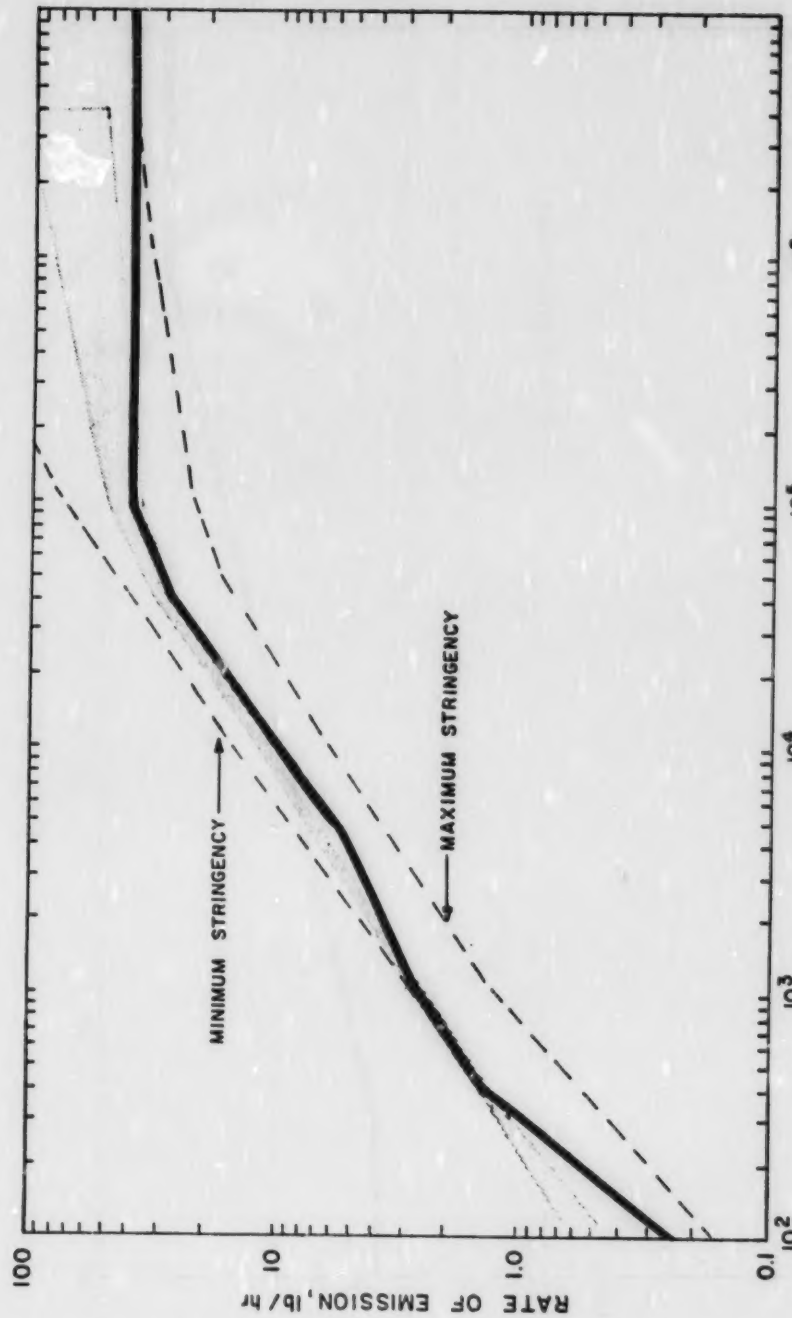


Figure 22. Process emissions regulations

Open Burning - Except for fire abatement and firemen training, recreation, and use of salamander heaters, open burning is prohibited.

The District of Columbia's emission standards for process equipment are approximately average for sources with a process weight rate of less than or equal to 50 tons per hour. Beyond that point the regulations are more stringent than the average and beyond a process weight rate of 200 tons per hour the regulations are the most stringent of the cities studied.

Only Baltimore is more stringent than the District for fuel burning equipment emission standards. D.C.'s regulations are substantially more stringent than the average. (More than one S_x from the mean). The D.C. emission rates for incinerators are also among the most stringent of the cities studied.

The District does not allow visible emissions except for startup, cleaning and adjustment operations. Most of the other cities allowed emissions no darker than No. 1 on the Ringelmann Chart.

Enforcement

The Bureau of Air and Water Quality in Washington, D.C. is responsible for surveillance and general field enforcement of regulations for air quality standards. The Bureau is concerned mainly with transportation, a major source of non-TSP pollutants. The Bureau also maintains the air quality monitoring network in the city. Air pollution point sources, including incinerators, are inspected on a complaint basis only. Most of the incinerators in the city have been closed, however, since the inception of the city's implementation plan for controlling air pollutants. Since there is no major industry in Washington, there is no major problem with particulate emissions from point sources.

IMPLEMENTATION PLANNING

Institutional Framework

The air pollution control program in the District is carried on by the D. C. Bureau of Air and Water Quality Control. Because of the unusual legal nature of the District, the Bureau is in effect required to function both as a State agency, with implementation planning and similar functions, and as a local agency, with field patrol, surveillance, and similar routine operational functions.

Close liaison is maintained with State and local agencies in Maryland and Virginia through regularly-scheduled meetings. The Metropolitan Washington Council of Governments (COG) has an Air Quality Planning Committee which undertakes regional coordination of planning activities; the Committee maintains a technical staff that can assist the agencies in such matters as transportation planning and emissions inventory development.

Implementation Planning Methodology

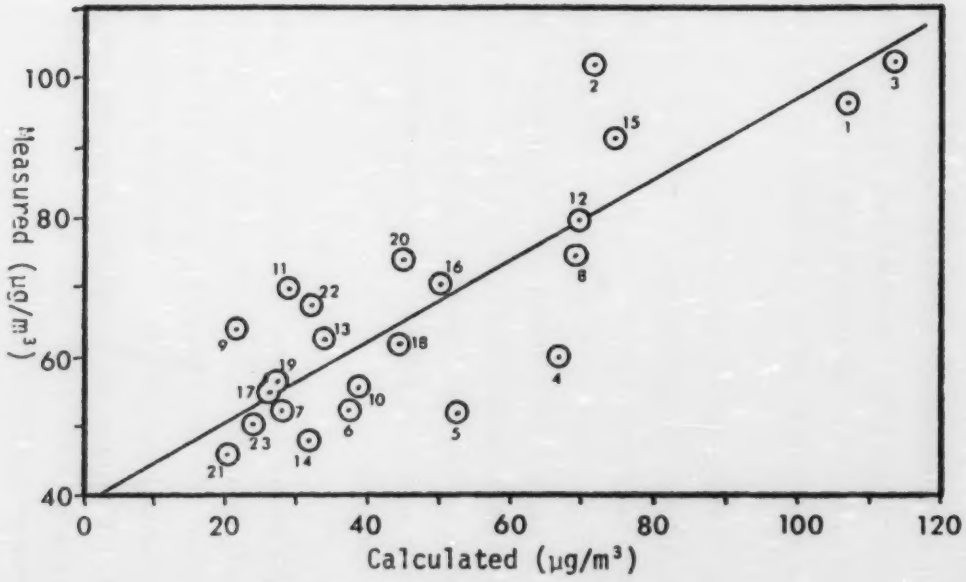
The NAPCA Emission Inventory of 1969 was used as the data base for particulate emissions in the implementation plan. The District contributed 20,050 tons per year, or 36 percent, of the particulate emissions in the NCIAQCR. The available data appears to have been adequate for prediction of growth and control strategies evaluation. There was enough data available to display according to source category, seasonal fluctuation, and geographical distribution. For a computer simulation, 100 point sources and 807 area sources were identified and characterized within the AQCR. A sample portion of the point source inventory is shown below (from: Implementation Plan for Controlling Sulfur Oxide and Particulate Air Pollutants, 1970; Appendix A):

	D.C.	NCIAQCR
Industrial Combustion Sources	1	9
Industrial Process Sources	0	8
Power Generating Units	10	22
Solid Waste Disposal Facilities	7	21
Housing Units	5	37
Governmental Facilities	25	56
Commercial Establishments	23	27
Total	71	180

A simulation model was developed for control strategy evaluation. This model included an atmospheric diffusion model which used the regional emission inventory and annual average meteorological data, a cost control model, and a control strategies model which applied emission reduction to the atmospheric diffusion model.

The air quality data used in the development of the SIP was from five stations operated by the Air Pollution Division Air Quality Monitoring Network, as well as from the CAMP station. The annual mean TSP level at the NASN site in 1968 was 91 $\mu g/m^3$; the other sites ranged from 71 $\mu g/m^3$ to 112 $\mu g/m^3$. For atmospheric diffusion model verification, the 1969 data from 23 monitoring sites within the AQCR were used. Only three sites were within the District, and only 6 months of data was available at the time. Figure 23 shows the result of the model verification calculations.

The calibration shows a general underprediction, and implies a background level of about 40 $\mu g/m^3$. The CAMP and NASN sites (Nos. 1 and 3) tend to determine the relationship, because of their high ambient levels; they are, of course, the two sites that have still not attained the standards in 1974. If those two sites had been omitted, the slope of the calibration relationship would have been much closer to 1.0, and the implied background in the 30 $\mu g/m^3$ range.



slope = 0.58

R = 0.83

y_0 = 38.5

Figure 23. Atmospheric diffusion model calibration relationship in the NCIAQCR (Locations of measuring stations are shown on Figure 24.)

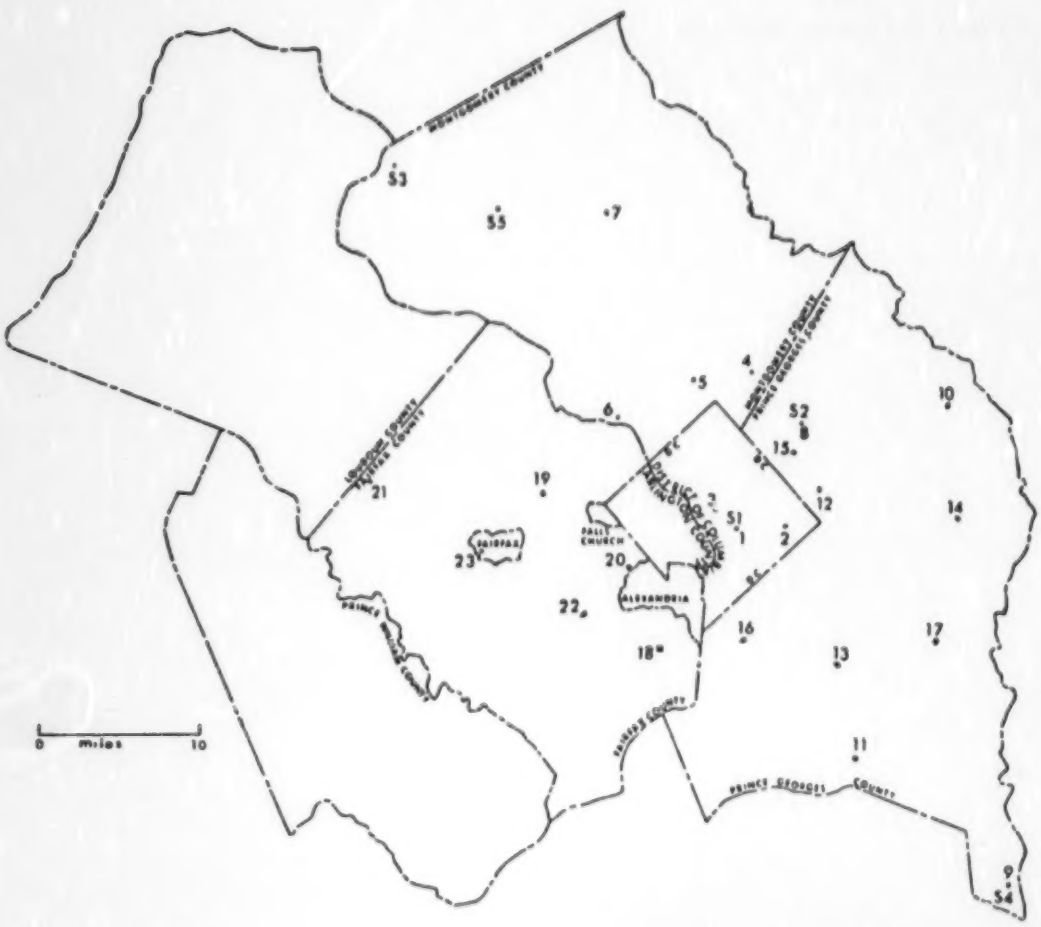


Figure 24. Location of air quality monitoring stations used in the model verification procedure in the NCIAQCR

A set of Control Regulations was selected and recommended, based upon the results of the computer simulation exercise using various control strategies. Factors such as regional population growth, transportation increases, and meteorological patterns were also considered. Given the regulations selected and the existing level of compliance, it was felt that estimates for the 1976 achievement of national standards for TSP levels were conservative.

SECTION III

SUMMARY AND CONCLUSION

SUMMARY

Air Quality

Two of the nine sampling sites regularly exceed the national and District of Columbia 24-hour and annual TSP standards. These are downtown sites, influenced by urban renewal, subway construction, and general transportation and human activity. Most sites did not begin sampling until the 1970's, and TSP levels have been declining since then, except for a city-wide upturn in 1974. The long-term trend at the NASN site shows a steady decrease in TSP levels from the start of its sampling in 1958 until the mid 1960's, when it appears to level off.

Sources and Emissions

The District of Columbia is a nonindustrial area. Washington's emissions are only 7,211 tons per year, which corresponds to a city-wide emission density of 108 tons/mi^2/year. About one-third of this is caused by electric power generation. Other point and area sources are on a much smaller scale. There has been a significant trend in fuel usage toward the cleaner fuels. Less coal is now being used and more gas and oil consumed, for residential as well as industrial and institutional purposes.

Transportation-related sources can be significant sources of pollution in Washington. The downtown monitoring sites show the highest

particulate levels, which may be the result of traffic congestion. However, the ADT on specific streets does not appear related to TSP, as was found in other cities, presumably because the hi-vols are not located to provide a consistent measure of traffic-related TSP. It is also probable that building construction around the various sites, especially downtown, influences TSP levels there, although specific data on fugitive emissions was not available.

An extensive transit and subway system is being constructed in the city. This has not resulted in demonstrably sizable increases in concentrations of suspended particulates, but at several sites frequent high levels occur when the wind generally blows from the construction area toward the monitor.

Meteorology and Climatology

Washington generally experiences a mild climate with average precipitation and no other outstanding climatological parameters, except for a relatively low mean afternoon mixing height. Its flat location on a river does not pose particular dispersion problems. Mild winters would allow seasonal emissions from space heating to be relatively low. In 1974, the city had lighter winds, more precipitation, and less heating demand than the long-term averages.

Regulations and Enforcement

The City of Washington's regulations regarding process weight rates and fuel burning are very stringent in comparison with other areas. With little incineration in the city, and hardly any major problematic point sources, there is little direct enforcement necessary in this area of particulate emissions. The Bureau of Air and Water Quality maintains the monitoring network for the city, engages in general field surveillance, and investigates emissions on a complaint basis.

Monitoring Network Design

Washington's nine operative sites in 1974 were located in areas adequately representative of the District: in commercial, institutional, residential, and downtown areas. Geographical distribution is covered, except for the east banks of the Potomac and Anacostia Rivers. Most of the monitors are situated in locations rather more remote than usual from normal traffic and human activity; e.g., on the tops of tall buildings and at large horizontal distances from streets.

APPENDIX A

PARTICLE CHARACTERIZATION

For most of the study cities members of the GCA study team acquired hi-vol filters from the 1974 filter banks of the cognizant local agencies. In addition, several filter samples for 1974 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than five percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Twenty-three filters from seven sites were selected for analysis in Washington and the meteorological data from National Airport for the selected sampling days are summarized in Table A-1. To gain some insight into the contribution of secondary particulates, much of which is too small to be observed by the microscopists, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table A-2. The results for each of the filters submitted for routine analysis are presented in Table A-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table A-4. Five filters underwent replicate analyses, and the results are presented in Table A-5.

The composite particulate characterization for all filters from Washington that underwent routine analysis, presented in Table A-6, shows that minerals predominate, comprising nearly three quarters of the TSP. Of the 14 study cities Washington was ranked sixth highest in average percent minerals. Quartz was the major constituent with somewhat lesser quantities of hematite and calcite. Although there were some site-to-site variations in the apparent composition of the TSP, there were no identifiable factors for the causes of the variations.

Washington was ranked second highest of the study cities in average percent biologicals even though the citywide average for the 23 filters analyzed was only 5 percent. It is apparent that biological materials, especially pollen, can sometimes have a significant impact on the TSP levels. On April 22, 1974, with moderate winds from the south-southwest, Washington apparently experienced very high levels of suspended pollen.

The four filters selected for analysis for that day ranged from 8 percent to 45 percent pollen, with most of the pollen identified as pine pollen. If the percent pollen identified on the filters can be multiplied by the TSP loadings for the filters for that day, then the 24-hour average concentration of pollen ranged from 13 $\mu g/m^3$ at the General Hospital to 154 $\mu g/m^3$ at the American Chemical Society site.

Table A-1. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (WASHINGTON, D.C.)

Date	Precipitation, in.		Wind speed, mph		Wind direction, deg	
	Day of obs.	Preceding day	Average	Resultant	3-hours obs.	Resultant
2/15/74	0	t	10.6	10.1	70, 40, 30, 40 30, 50, 50, 90	50
2/21/74	0	0.01	5.3	4.5	210, 240, C, C 200, 190, 130, 170	[illegible]
2/24/74	0	t	9.4	9.0	50, 50, 80, 80 80, 100, 100, 80	80
4/01/74	t	0.01	6.0	1.1	260, 320, 330, 180 30, 130, 150, 60	90
4/22/74	0.03	0	14.2	14.2	200, 200, 210, 210 210, 210, 210, 210	210
8/14/74	0.12	t	6.3	2.0	210, 210, 30, 330 230, 330, 100, 260	290
8/23/74	t	0.27	6.5	5.8	240, 270, C, 240 200, 180, 190, 210	210
10/25/74	t	0	7.5	5.1	200, 200, 200, 190 180, 200, 330, 330	210

Note: C = Calm
t = Trace

Tavle A-2. ANNUAL AVERAGE CONCENTRATION OF SULFATE AND NITRATE IONS AT THE WASHINGTON, D.C. NASN SITE NO. 090020001 ($\mu g/m^3$)

Year	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1972	13.83[a]	12.86[a]	2.88[a]	2.52[a]
1973	10.66[a]	9.66[a]	3.11[a]	2.79[a]
1974	12.95[a]	12.13[a]	3.25[a]	2.77[a]

[a]Indicates insufficient data for statistically valid year.

Table A-3a. RESULTS OF FILTER ANALYSES — SELECTED SITES IN WASHINGTON, D. C. (AMERICAN CHEMICAL SOCIETY — ACS)

Date	21 February 1974			1 April 1974			22 April 1974			23 August 1974			25 October 1974		
TSP ($\mu g/m^3$)	113			89			342			56			85		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(7+)			(6+)			(4)			(6+)			(8)		
Quartz	4+	<1-60	5	3	<1-70	5	1+	<1-50	3	2	1-100	5	4	<1-40	3
Calcite	1	<1-60	5	1	<1-40	5	1	<1-50	5	1	<1-20	5	2	<1-30	5
Feldspars	1-						1-			1-			1-		
Hematite	1+	<1-20	0.5	2	<1-40	0.5	1	<1-40	0.5	3	<1-30	0.5	1+	<1-60	0.5
Mica															
Combustion Products	(2+)			(4+)			(1+)			(1)			(2)		
Soot:															
Oil															
Coal	1	<1-100	0.5	2	<1-150	0.5	1	<1-150	0.5	1-	<1-150	0.5	2	<1-150	0.5
Glassy fly ash	1	<1-12	6	1+	<1-30	6									
Incinerator fly ash															
Burned wood															
Burned paper															
Magnetite															
Biological Materials	(0+)			(0+)			(5-)			(1-)			(0+)		
Pollen							4+	20-60	40						
Spores															
Paper															
Starch															
Misc. plant tissue															
Miscellaneous	(0+)			(0+)			(0+)			(2)			(0+)		
Iron or steel															
Rubber										1	<1-250	25			
Glass										1	1-100	75			

Table A-3b. RESULTS OF FILTER ANALYSES — SELECTED SITES IN WASHINGTON, D. C. (NEVEL THOMAS SCHOOL — NTS)

Date	15 February 1974			21 February 1974			24 February 1974			22 April 1974			23 August 1974			25 October 1974		
TSP ($\mu g/m^3$)	72			66			99			186			61			115		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(8+)			(8+)			(7)			(8)			(8-)			(7)		
Quartz	2	<1-150	1	3	<1-50	3	3+	<1-30	2	4	<1-60	5	4	<1-40	3	1+	<1-60	3
Calcite	4+	<1-100	1	4	<1-60	3	2	<1-30	2	1	<1-50	5	1+	<1-30	5	1-	<1-50	5
Feldspars													1-			1-		
Hematite	1+	<1-20	0.5	1+	<1-30	0.5	1+	<1-30	0.5	2+	<1-30	0.5	2-	<1-20	0.5	4	<1-30	0.5
Mica																		
Clays																1-	<0.5	<0.5
Combustion Products	(2-)			(1+)			(3)			(1+)			(2+)			(3)		
Soot:																		
Oil	1	<1-80	0.5	1	<1-150	0.5	2	<1-300	0.5	1-			1+	<1-100	0.5	2+	<1-100	0.5
Coal	1-						1-			1-			1-			1-		
Glassy fly ash							1-			1-			1-					
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																		
Biological Material	(0+)			(0+)			(0+)			(1)			(0+)			(0+)		
Pollen										1	10-60	50						
Spores																		
Paper																		
Starch																		
Misc. plant tissue																		
Miscellaneous	(0+)			(0+)			(0+)			(0+)			(0+)			(0+)		
Iron or steel																		
Rubber																		

Table A-3c. RESULTS OF FILTER ANALYSES — SELECTED SITES IN WASHINGTON, D. C. (CATHOLIC UNIVERSITY — CU)

Date	21 February 1974			1 April 1974			22 April 1974			14 August 1974			23 August 1974			25 October 1974		
TSP ($\mu g/m^3$)	101			64			138			123			48			103		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(6+)			(5)			(6+)			(6-)			(7+)			(7)		
Quartz	2+	<1-80	3	1+	<1-60	3	3	<1-80	2	3	<1-250	6	4	<1-70	5	2	<1-80	3
Calcite	2	<1-70	3	1+	<1-60	3	1+	<1-6	4	1-	<1-30	5	1+	<1-60	5	1	<1-50	5
Feldspars				1-									1-					
Hematite	1+	<1-20	0.5	1+	<1-60	0.5	1+	<1-40	0.5	2	<1-	0.5	1+	<1-50	0.5	4	<1-50	0.5
Mica																		
Combustion Products	(4-)			(5)			(1+)			(3)			(2+)			(2)		
Soot:																		
Oil																		
Coal	3	<1-200	0.5	2	<1-150	0.5	1	<1-150	0.5	1-	<1-200	0.5	1	<1-150	0.5	1+	<1-200	0.5
Glassy				1-						1-	<1-50	20						
fly ash	1-	<1-20	6	2+	<1-30	6	1-			2	<1-30	6	1	<1-50	5	1-	<1-12	6
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																		
Biological Material	(0+)			(0+)			(2)			(0+)			(0+)			(0+)		
Pollen																		
Spores							2	20-60	50									
Paper																		
Starch																		
Misc. plant tissue																		
Miscellaneous	(0+)			(0+)			(0+)			(1)			(0+)			(1-)		
Iron or steel																		
Rubber																		
Iron rust										1	<1-250	50				1-	<1-200	75

Table A-3d. RESULTS OF FILTER ANALYSES — SELECTED SITES IN WASHINGTON, D. C.

Site	D. C. General Hospital — DCG						CAMP — CA						Cleveland Park — CO			National Arboretum — NA		
Date	1 April 1974			22 April 1974			14 August 1974			23 August 1974			14 August 1974			25 October 1974		
TSP ($\mu g/m^3$)	60			44			47			110			125			47		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(7)			(6+)			(7)			(8+)			(8+)			(8)		
Quartz	4	<1-50	5	4	<1-80	5	3+	<1-80	2	3+	<1-100	3	6	<1-20	5	1+	<1-60	3
Calcite	1	<1-40	5	1	<1-40	5	1+	<1-70	5	1	<1-80	5	1-	<1-20	5	1	<1-60	5
Feldspars	1-			1-			1-			1-						1-		
Hematite	2-	<1-40	0.5	1	<1-40	0.5	1+	<1-30	0.5	3+	<1-30	0.5	1+	<1-50	0.5	5	<1-50	0.5
Mica																		
Combustion Products	(3-)			(1-)			(3)			(2-)			(1+)			(2)		
Soot:																		
Oil	1	<1-150	0.5				2+	<1-150	0.5	1-	<1-200	0.5	1-	<1-100	0.5	1	<1-200	0.5
Coal										1-						1-		
Glassy fly ash	1	1-20	6				1-			1-	<1-20	6	1	<1-15	5	1-		
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																		
Biological Material	(0+)			(3)			(0+)			(0+)			(0+)			(0+)		
Pollen				3	20-60	50												
Spores																		
Paper																		
Starch																		
Misc. plant tissue																		
Miscellaneous	(0+)			(0+)			(0+)			(0+)			(0+)			(0+)		
Iron or steel																		
Rubber																		

Table A-3e. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN WASHINGTON, D.C.

Site	NASN – No. 090020001			NASN – No. 090020003		
Date	25 December 1974			25 December 1974		
TSP ($\mu g/m^3$)	NA			NA		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(5)			(6)		
Quartz	3	<1-150	2	4	<1-200	2
Calcite	1	<1-100	2	1	<1-100	2
Feldspars	0+			0+		
Hematite	1	<1-100	0.5	1-	<1-20	0.5
Mica						
Combustion Products	(3)			(2-)	<1-100	0.5
Soot:						
Oil	1-			1		
Coal	1-	<1-100	30	1-		
Glassy fly ash	2	<1-100	20	0+		
Incinerator fly ash						
Burned wood						
Burned paper				<1		
Magnetite						
Biological Material	(<1)			(<1)		
Pollen	<1					
Spores	<1			<1		
Paper	<1			<1		
Starch	<1			<1		
Misc. plant tissue	<1			<1		
Miscellaneous	(2)			(2+)		
Iron or steel	<1			<1		
Rubber	2	<1-200	30	2+	<1-150	30

Table A-4. COMPOSITE SUMMARY OF FILTER ANALYSES – SELECTED SITES IN WASHINGTON, D.C.

Site	Nevel Thomas School – NTS		Catholic University – CU		American Chem. Soc. – ACS		D. C. General Hospital – DCG		CAMP – CA		Cleveland Park – CO	National Arboretum – NA	NASN No. 090020001	NASN No. 020090003
No. of filters	6		6		5		2		2		1	1	1	1
	Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent	Quantity, percent	Quantity, percent	Quantity, percent
Components	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	–	–	–	–
Minerals	(78)	69-87	(63)	49-74	(65)	39-79	(68)	65-72	(76)	69-84	(85)	(79)	(51)	(56)
Quartz	30	15-40	27	15-40	30	15-45	40	40	35	35	60	15	30	40
Calcite	23	5-45	13	5-20	13	10-20	10	10	12	10-15	7	10	8	10
Feldspars	3	2-4	3	2-4	4	3-4	4	4	4	4	2	4	3	3
Hematite	21	15-40	20	15-40	18	10-30	13	10-17	25	15-35	15	50	10	5
Mica	<1	0-<1	<1	0-<1	<1	0-1	1	0-1			1			
Clay	1	0-5												
Combustion Products	(21)	13-31	(30)	16-49	(21)	10-37	(16)	5-26	(24)	16-31	(15)	(18)	(29)	(17)
Soot:														
Oil	14	4-25	15	5-30	13	5-26	6	2-10	16	6-25	5	10	4	10
Coal	4	1-4	3	2-5	2	1-3	2	1-3	3	2-4	<1	4	5	4
Glassy fly ash	3	2-4	12	4-20	6	<1-15	6	2-10	5	4-6	10	4	20	3
Incinerator fly ash	<1	<1-2	<1		<1	<1-2	1	0-2	<1		<1	<1		
Burned wood	<1		<1		<1		<1				<1			
Burned paper	<1		<1		<1		1	0-1	<1		<1	<1		<1
Magnetite														
Biological Material	(1)	(<1-8)	(4)	<1-21	(10)	<1-47	(16)	2-30	(<1)		(<1)	(3)	(<1)	(<1)
Pollen	1	0-8	3	<1-20	9	<1-45	15	<1-30	<1		<1	<1	<1	
Spores	<1		<1		<1		<1		<1		<1	<1	<1	<1
Paper	<1		<1		<1		<1		<1			<1	<1	<1
Starch			<1		<1		<1		<1				<1	<1
Misc. plant tissue	<1		1	<1-1	1	<1-3	1	0-2	<1		<1	3	<1	<1
Miscellaneous	(<1)		(3)	<1-10	(4)	<1-20	(<1)		(<1)		(<1)	(<1)	(20)	(25)
Iron or steel	<1		<1		<1		<1		<1		<1		<1	<1
Rubber	<1		<1	0-1	2	0-10	<1		<1			<1	20	25
Iron rust			3	0-10										
Glass					2	0-10								

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Table A-5. RESULTS OF REPLICATE ANALYSES OF WASHINGTON, D. C. FILTERS

Site	American Chemical Society – ACS					Catholic University – CU				D. C. General Hospital – DCG	
Date	21 Feb. 1974		22 April 1974			1 April 1974		23 Aug. 1974		22 April 1974	
TSP ($\mu g/m^3$)	113		342			64		48		44	
Laboratory	A	A	A	A	B	A	B	A	B	A	A
Analysis	1	2	1	2	1	1	1	1	1	1	2
Components											
Minerals	(74)	(30)	(39)	(62)	(27)	(49)	(15)	(74)	(48)	(65)	(62)
Quartz	45	20	15	30		15		40		40	30
Calcite	10	5	10	20		15		15		10	20
Feldspars	4		4	2		4		4		4	2
Hematite	15	4	10	10		15		15		10	10
Mica	<1							<1		1	
Combustion Products	(25)	(69)	(14)	(8)	(37)	(49)	(84)	(24)	(52)	(5)	(8)
Soot:											
Oil	10	7	10	5	7	20	8	12	8	2	5
Coal	5	20	2	1		4		2		1	1
Glassy fly ash	10	40	2	2	30	25	76	10	44	2	2
Incinerator fly ash	2		<1			<1		<1			
Burned wood	<1										
Burned paper	<1					<1					
Magnetite											
Coked coal		2									
Biological Material	(<1)	(<1)	(47)	(25)	(36)	(1)	(1)	(1)	(<1)	(30)	(25)
Pollen	<1		45	25		1		<1		20	25
Spores	<1		<1	<1		<1		<1		<1	<1
Paper	<1	<1	<1	<1		<1		<1			<1
Starch	<1							<1			
Misc. plant tissue	<1	<1	2	<1		<1		1			<1
Miscellaneous	(1)	(1)	(<1)	(5)	(<1)	(1)	(<1)	(1)	(<1)	(<1)	(5)
Iron or steel	<1	<1	<1	<1		<1		<1		<1	<1
Rubber	1	1		5		1		1			5

Table A-6. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSES IN WASHINGTON, D.C.

No. of filters	25	
	Quantity, percent	
Components	Average	Range
Minerals	(70)	39-87
Quartz	31	15-60
Calcite	15	5-45
Feldspars	3	2-4
Hematite	20	10-50
Mica	<1	
Other	<1	
Combustion Products	(23)	5-49
Soot:		
Oil	13	2-30
Coal	3	<1-5
Misc. soot		
Glassy fly ash	7	<1-20
Incinerator fly ash	<1	
Burned wood	<1	
Burned paper	<1	
Magnetite		
Carbon black		
Other		
Biological Material	(5)	<1-47
Pollen	4	<1-45
Spores	<1	
Paper	<1	
Starch	<1	
Misc. plant tissue	1	0-3
Leaf trichomer		
Miscellaneous	(2)	<1-25
Iron or steel	<1	
Rubber	2	0-25
Other	<1	0-10

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of fourteen single-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Particulate Matter Total Suspended Particulate Emission Sources Control Methods Air Quality Measurements	Optical Microscopy Secondary Particulates Fuel Combustion Process Emissions Fugitive Emissions Fugitive Dust Monitor Siting Meteorology	

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